REPORT RESUMES

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MANUAL OF LECTURE DEMONSTRATIONS, LABORATORY EXPERIMENTS, AND OBSERVATIONAL EQUIPMENT FOR TEACHING ELEMENTARY METEOROLOGY IN SCHOOLS AND COLLEGES.

BY- NEUBERGER, HANS NICHOLAS, GEORGE
PENNSYLVANIA STATE UNIV., UNIVERSITY PARK

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INCLUDED IN THIS MANUAL WRITTEN FOR SECONDARY SCHOOL AND COLLEGE TEACHERS ARE DESCRIPTIONS OF DEMONSTRATION MODELS, EXPERIMENTS PERTAINING TO SOME OF THE FUNDAMENTAL AND APPLIED METEOROLOGICAL CONCEPTS, AND INSTRUCTIONS FOR MAKING SIMPLE WEATHER OBSERVATIONS. THE CRITERIA FOR SELECTION OF TOPICS WERE EASE AND COST OF CONSTRUCTING APPARATUS AS WELL AS THE AVAILABILITY OF MATERIALS. SECTIONS ON GENERAL AND SPECIAL REQUIREMENTS LIST TOOLS REQUIRED TO BUILD THE APPARATUS, INEXPENSIVE ITEMS WHICH MUST BE PURCHASED, AND DIRECTIONS FOR BUILDING SUCH APPARATUS AS LIGHT STANDS, BALANCES, AND SMOKE SOURCES. FOR EACH OF THE DEMONSTRATION MODELS AND EXPERIMENTS IN THE MANUAL THERE ARE (1) A BRIEF DISCUSSION OF THE SCIENCE CONTENT INVOLVED, (2) A LIST OF MATERIALS, (3) DIRECTIONS FOR BUILDING AND USING THE APPARATUS, INCLUDING DIAGRAMS OR PHOTOGRAPHS, AND (4) AN ESTIMATED COST. THE SECTION ON OBSERVATIONS INCLUDE SUCH WEATHER PHENOMENA AS RELATIVE HUMIDITY, AIR PRESSURE, PRECIPITATION, AND CLOUD FORMATIONS. APPENDED IS A LIST OF INEXPENSIVE READING MATERIALS, INCLUDING BOOKS AND PERIODICALS. THIS DOCUMENT IS AVAILABLE FOR $2.00 FROM THE PENNSYLVANIA STATE UNIVERSITY, DEPARTMENT OF METEOROLOGY, 422 MINERAL INDUSTRIES BUILDING, UNIVERSITY PARK, PENNSYLVANIA 16802. (DG)

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THE MINERAL INDUSTRIES EXPERIMENT STATION
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MANUAL OF LECTURE DEMONSTRATIONS, LABORATORY EXPERIMENTS, AND OBSERVATIONAL EQUIPMENT FOR TEACHING ELEMENTARY METEOROLOGY IN SCHOOLS AND COLLEGES

By

Hans Neuberger
and
George Nicholas

Department of Meteorology

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INTRODUCTION

This manual should not be considered a substitute for a textbook in elementary meteorology; its aim is to furnish descriptions of demonstration models and experiments pertaining to some of the fundamental and applied meteorological concepts, and instructions for making simple weather observations. The guiding principle for the selection of topics was the restriction to easily and inexpensively constructed apparatus and to easily available materials.

The treatment of this manual is by no means exhaustive, although several experiments contain alternatives for constructions and materials. Instructors and students can probably invent many variations and use other available materials. Refinements with more expensive equipment can be achieved, where funds are available. Also, in most cases, the apparatus can be made larger or smaller as desired; where a metal workshop is available, wood or cardboard can often be replaced by sheet metal. The costs cited at the end of each experiment represents an approximate figure for the major materials as described, that may have to be purchased; not included are minor items such as a few nails, a drop of glue or cement, a few inches of scotchtape or masquing tape, a tumbler or glass jar (which students can bring from home), or empty tin cans. It was also assumed that paper clips, birthday candles, and short stubs of larger candles are available.

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Notice The mention of any commercial product in this manual is not to be construed as an endorsement by the authors, The Pennsylvania State University, nor the National Science Foundation.

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I. GENERAL REQUIREMENTS

A. Tools:

For the construction of many of the subsequently described apparatus the following tools will be needed: hammer; tin shears or old, short, sturdy scissors; small pointed pliers to bend wire, preferably with wire cutter; awl or ice pick for making holes, but a large nail with sharpened point can be used instead; hack saw; hand saw, but hack saw can be used instead; coarse round file or round rasp; screw driver medium size; assorted sand paper. Helpful, but not necessary are a coping saw, a drill with various bit sizes, a square, a rasp, a flat file (fine).

B. Heat Sources:

In several experiments, a heat source is needed. For this a Bunsen burner is ideal, but a Sterno cooking stove (Sterno canned heat) is quite adequate. In some cases, one or more candles are sufficient. A gasoline or kerosene stove is not recommended. An electric hot plate can also be used, except for heating wires, in which case a candle will do.

C. Light and Radiation Sources:

Where a strong light beam is required, sunlight is the cheapest source, which is also a good radiation source. A strong flashlight or a slide or movie projector can be used. For diffuse light or radiation an ordinary light bulb of 75 to 200 watt can be used; this can be mounted on an adjustable stand or in a gooseneck lamp (see also section III, A). Fluorescent light cannot be used.

D. Timing:

When time has to be measured, a watch or a wall clock with second hand are needed. In some experiments, a stop watch is handy, but not necessary.

E. Water Source:

Where water is required, ordinary tap water, clean spring or well water is fine.

F. Thermometers:

At least two thermometers are needed, but preferably more are to be acquired. A total of eight thermometers is recommended, five of which are mounted for weather observation purposes. The other three are for laboratory experiments. The thermometers need not be expensive ones; those found in five-and-ten-cent stores for 30 to 70¢ a piece are adequate, but care should be taken that the thermometers read all the same, although this does not assure correct calibration. Check also that none of the red liquid in the capillary is separated from the main column and stuck somewhere in the empty portion of the capillary. Window thermometers that are enclosed into a glass tube or other material should be removed from the tubing in which they are mounted except one for experiment 12. The thermometers should have the capillary tubing mounted firmly on the scale. Floating fish-bowl thermometers are good, but have to be handled with special care. Check to see that the 32° F mark, that is etched on the side of the capillary, coincides with the 32° F line on the scale. Some thermometers have a calibration mark at 70° F or other temperatures. It is, nevertheless, recommended that the thermometers be immersed into an ice-water mixture for check of the melting point, and that corrections be applied to the thermometer readings, when necessary. Other scale readings are difficult to check unless another well-calibrated laboratory thermometer is available. Note that the price of most thermometers purchasable in ordinary stores is no indication of the quality, but usually reflects the cost of the thermometer backing; wood is usually more expensive than metal or plastic. Thermometers with metal scale, mounted in plastic frames, are specially recommended, as they can be very easily detached from their frames for the experiments.

G. Other Materials

It is good to acquire an assortment of empty food tin cans of various sizes; also rectangular detergent, gasoline or oil cans will come to good stead, but the cans that contained any inflammable liquid should be thoroughly cleaned before they are used, to eliminate fire or explosive hazards. Plastic bottles with screw caps and nozzles (detergent, relish, cosmetic bottles, etc.) are also needed.

An assortment of scrap wood (sticks, molding, board, dowel rods) can be acquired from a lumber yard, hardware store or similar source, usually very inexpensively, if not gratis. (The cost estimates of the apparatus include the purchase price of wood.)

The use of glass tubing has been avoided, because it is not generally available. But where it is obtainable and where facilities for working it are present, glass tubing can be used instead of eye droppers and drinking straws in several experiments.

II. IMPORTANT NOTICE

In the subsequent descriptions of apparatus, the dimensions specified are more or less arbitrary, with a few exceptions that are specially emphasized. Otherwise, if, e.g., a stick of wood of 3/4 x 3/4 x 15" is specified, one of 1/2 x 1/2 x 13" or 1 x 1 x 17" or 1/2 x 1 x 16-1/2" is equally usable. In other words, the general shape and proportions of the apparatus is more important than the specific sizes of the component parts; for this reason, photographs of the finished equipment are included.

Before starting an experiment or constructing a demonstration apparatus, the pertinent meteorological aspects should be studied in a textbook. Then the section in this manual should be read completely and carefully, including the illustrations.

III. SPECIAL REQUIREMENTS

A. Stand for Light and Radiation Source

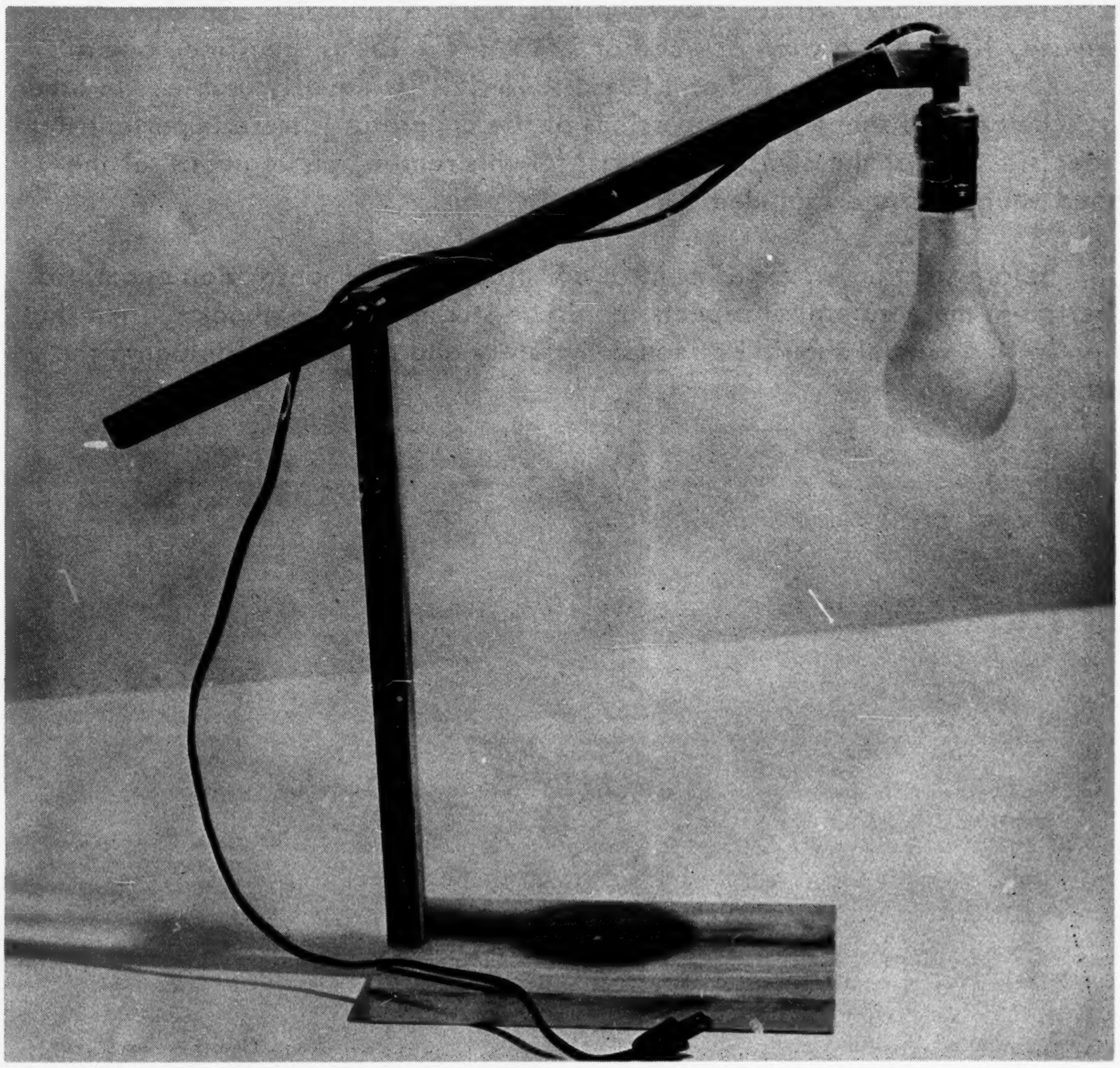


Plate 1.

Where no adjustable stand for a lightbulb is available, a simple one can be constructed as follows.

Make a notch, 3/4 x 3/4" into the middle of one short edge of a piece of wood board, 3/4 x 5 x 10". Glue and nail upright into this notch a stick of wood, 3/4 x 3/4 x 15". A 1/4" hole is drilled (or burned with a large nail) near the upper end of the stick. Cut two strips of wood (plywood or molding) each 18" long, 3/4" wide, and 3/16" thick. Lay the two strips on one another and bore five 1/4" holes, 3" apart, starting at one end of the strips and another hole at the other end (Fig. 1.). Bore a 1/4" hole about 1" from the end of a short piece of wood 3/4 x 3/4 x 3" and another, larger hole at right angles to the first one, to accomodate the socket of a lightbulb (Fig. 2.). The socket should preferably have a switch.

Assemble the pieces with stove bolts and nuts with washers between the wood and the bolt heads and nuts. The arm of the stand can be lengthened or shortened by proper selection of the holes; the arm can also be raised and lowered to any selected height (See Plate 1).

Material: One piece of wood 3/4 x 5 x 10"
One piece of wood 3/4 x 3/4 x 15"
Two strips of wood 3/8 x 3/4 x 18"
One lightbulb socket with switch, electric cord and plug
One piece of wood 3/4 x 3/4 x 3"
Two stove bolts 1/4 x 1-1/2" with nuts
Four washers
One 2" brad; glue

Cost: 80¢

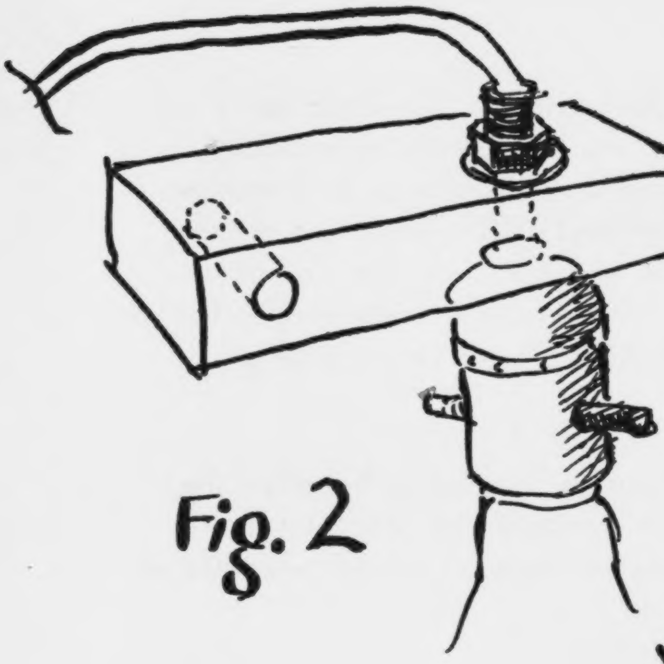


Fig. 2

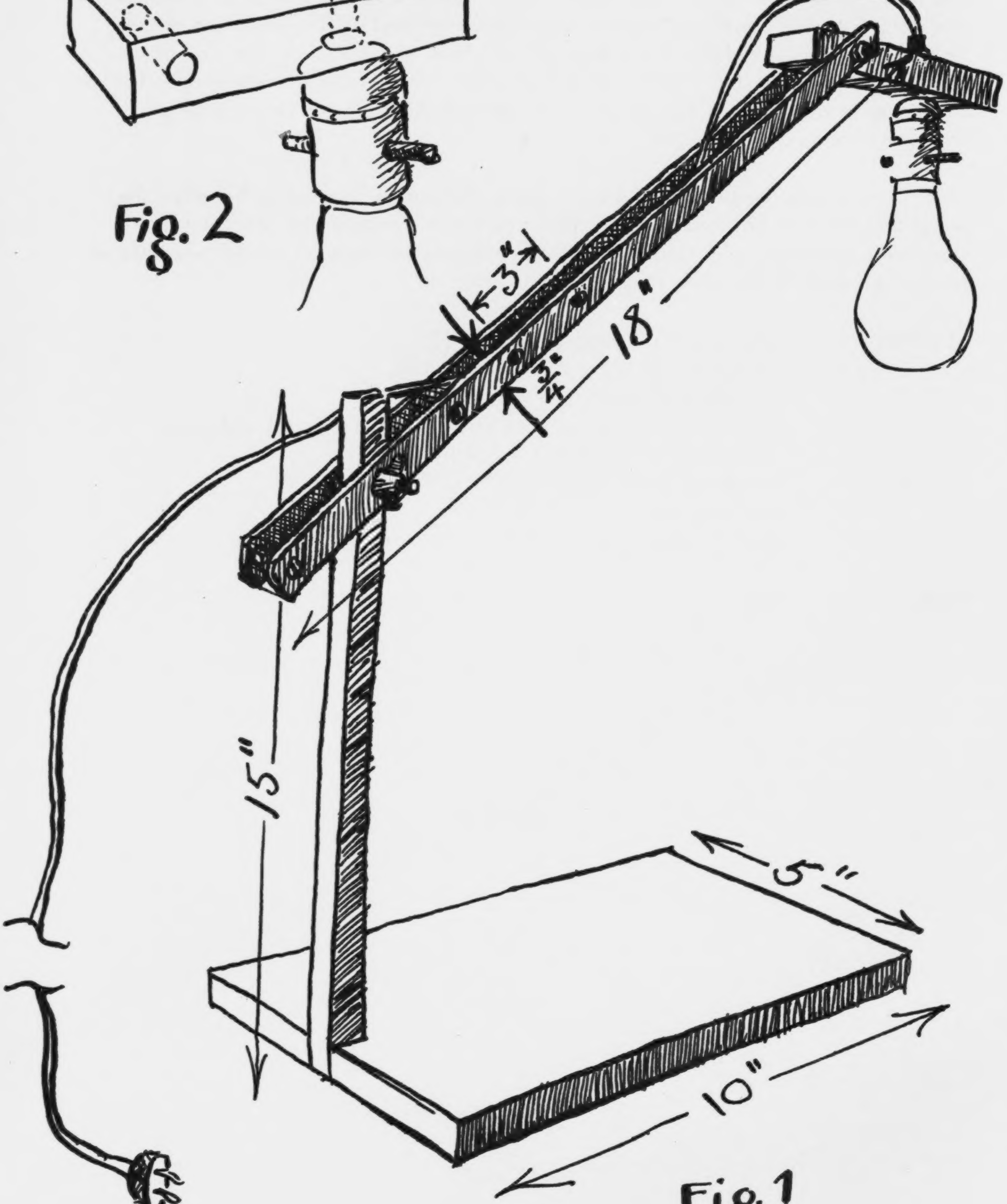

3"
3/4"
18"
15"
5"
10"

Fig. 1

B. Balance Construction

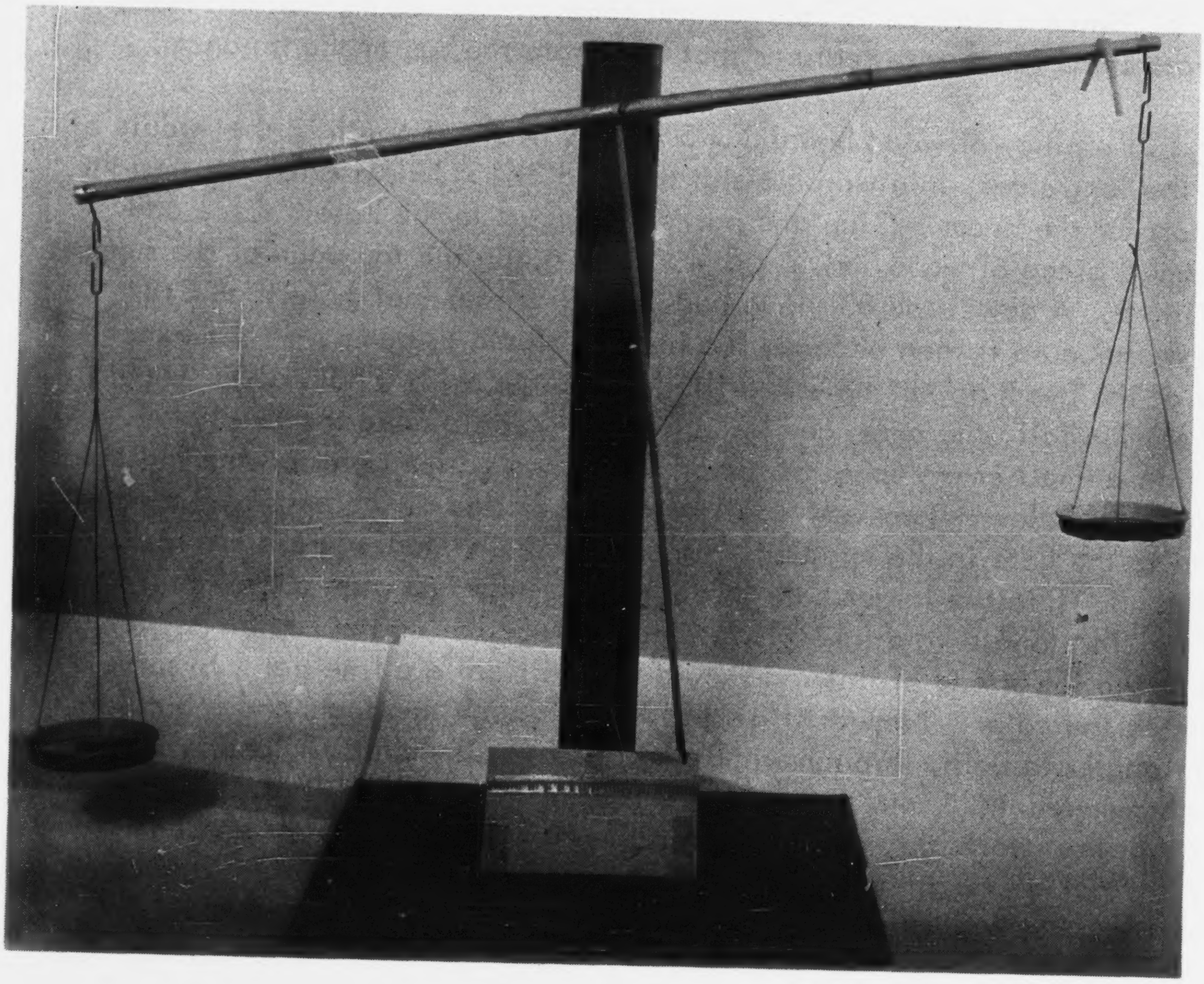


Plate 2.

Several of the experiments require the use of a balance. Household scales are not usable for the purposes of the experiments, and analytical balances are not appropriate. Balances of adequate sensitivity can be easily made as follows:

a) Any straight, light stick of wood 2 to 3 feet in length, suspended on a thread tied around the middle of the stick is sufficient. To hang the experimental objects and counterweights on the beam of the balance, small holes can be drilled (or burned with a hot nail) through the ends; a paper clip straightened out (or similar wire) and cut in two equal pieces are inserted through the holes and bent into a loop at the top, into a hook at the bottom. (Fig. 3). The disadvantage of this type of balance is the freedom of the beam to rotate in the horizontal plane around the suspending thread. This can be overcome by drilling or burning a small hole horizontally through the beam in the exact middle and putting a stiff wire (straightened paper clip), bent into an "L"-hook, through as a pivot (Fig. 4). The wire should sit loosely in the hole and can be taped over the edge or corner of a table.

b) Since a balance is used several times, it is recommended to make a separate stand for it with features that facilitate the use of the balance.

Cut a piece of wood board 1 x 5 x 12". Make a notch in the middle of one of the long sides, into which a slat of wood 3/4 x 1-1/2 x 16" fits upright, as support for the beam. Glue and nail this support to the base. Glue and nail a small piece of wood 1-1/2 x 3/4 x 3/4" along the top edge of the support as in Fig. 5. A dowel rod 30" long and 1/4" diameter (not more than 3/8" diameter, because it then becomes too heavy) is used as beam. In the exact middle of the beam a 1/8" hole is drilled (or burned with a hot nail). Should this operation fail, the beam can be cut in the middle, and the two halves glued into a small empty spool of thread; it is then easier to fasten the indicator rod described below. Two very small holes are drilled at the ends of the beam parallel to the hole in the middle. Through these end-holes hooks are fastened as in Fig. 3. Into the larger hole in the middle push and glue a straight 1/8" dowel rod 14" long (two drinking straws taped together and cut to proper length will do); the lower end of this rod should be whittled to a fine point to serve as balance indicator. Now drill a small hole through the beam and indicator at right angles to both, through which a 1" pivot nail should fit loosely. The nail is hammered 1/2" into the middle of the top of the stand (Fig. 6). If two glass beads are available, place them on the nail to each side of the beam; otherwise, a 1/4" length of a drinking straw put on the nail between the beam and the stand-top will prevent the beam from rubbing against the stand. The beam should come to rest in a horizontal position without any load, so that the indicator is vertical. If the balance is slightly askew, hang a small strip of paper on the higher end of the beam and trim it with scissors until a balance is achieved. Make a scale on a piece of white stiff cardboard about 6 x 2"; the length of the scale should be about 5" with the divisions 1/8" apart. Every 5th division should be a little longer than the others for easier counting, and the center of the scale should be marked "0". The scale is then taped at an angle under the balance indicator with the pointed end of the indicator directly over the "0", as shown in Fig. 6.

As counterweights, a chain of paper clips can best be used. For fine adjustment of the balance, a rider is made from a 3" piece of drinking straw bent into an up-side-down "V"; this rider is then placed on the high side of the beam and shifted until balance is achieved. Riders can also be made from wire or an empty spool of thread can be placed over the beam as in Fig. 7.

Material:
One 1/4" or 3/8" dowel rod, 30" long.
One 1/8" dowel rod, 14" long.
Wood board 1 x 5 x 12".
Wood slat 3/4 x 1-1/2 x 16".
Paper clips.
Glue and Nails.

Cost: 25¢

c) If no wood is available, a serviceable balance can be made entirely of cardboard and paper. As a base we take a heavy stiff piece of cardboard about 8-1/2 x 11"; if only relatively flexible cardboard is available (such as backs of notebook pads), two or three such sheets can be pasted or stapled together. The support is made of a mailing tube of 1 to 2" diameter and 12 to 18" length; also two cores of paper-towel rolls can be taped together, to make a long tube. At one end of the tube incisions are made with scissors, about 1-1/2" deep and 1/2" apart; this tube-end is then flared out and pasted on the base a little off center as shown in Fig. 8.

To make the beam, we roll two sheets of good-grade writing paper 8-1/2 x 11" diagonally over a pencil, tape the end, and push the pencil out (Fig. 9). We lay the two paper tubes end to end, tightly roll another sheet of paper 4-1/4 x 11" over them as shown in Fig. 10, and glue or tape the end of the roll. For reinforcement we also put one turn of scotchtape over the ends of the paper tubes and put at each end a hook as in Fig. 3.

As indicator two drinking straws are firmly taped together end to end; at the upper end we make an incision 1" deep, bend the straw apart, and fasten with tape to the exact middle of the beam, so that the indicator is at right angles to the beam. To keep it in this position, we put (with a sewing needle) a strong thread through the middle of the indicator and the middle of each side of the beam as in Fig. 11. A scale as in Fig. 6 is fastened to the base and support. The beam is pierced with a stiff wire and fastened to the top of the support as in Fig. 12.

Material:	One heavy cardboard 8-1/2 x 11". One mailing tube 15" long, 2" diameter. Three sheets of good paper 8-1/2 x 11". Two drinking straws. Paper clips, glue, scotch tape.

Cost: 10¢

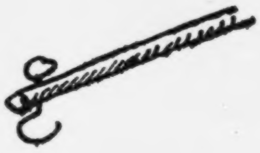


fig. 3

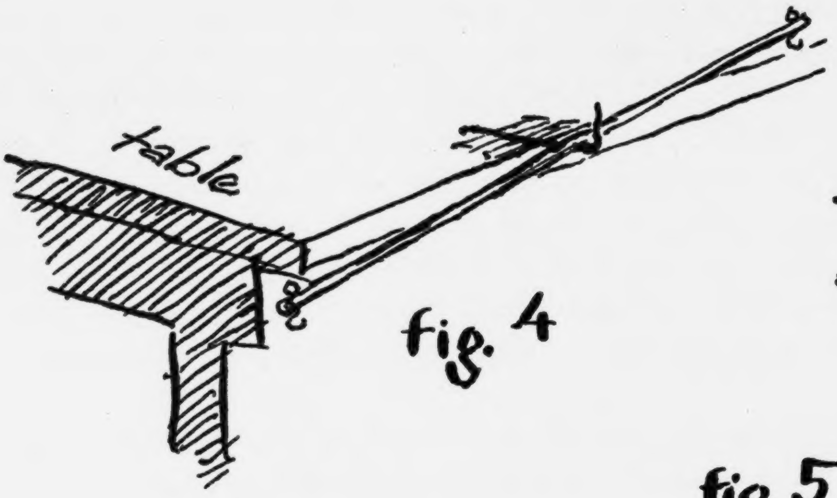


fig. 4

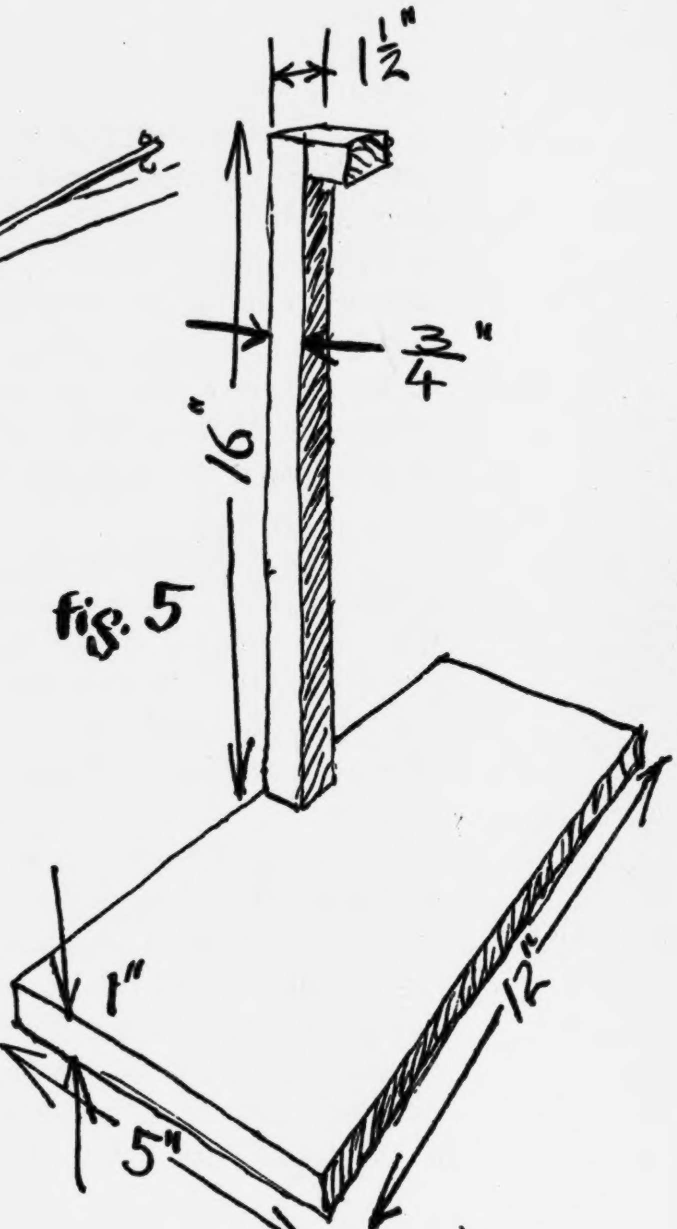

1½"
3/4"
16"
1"
5"
12"

fig. 5

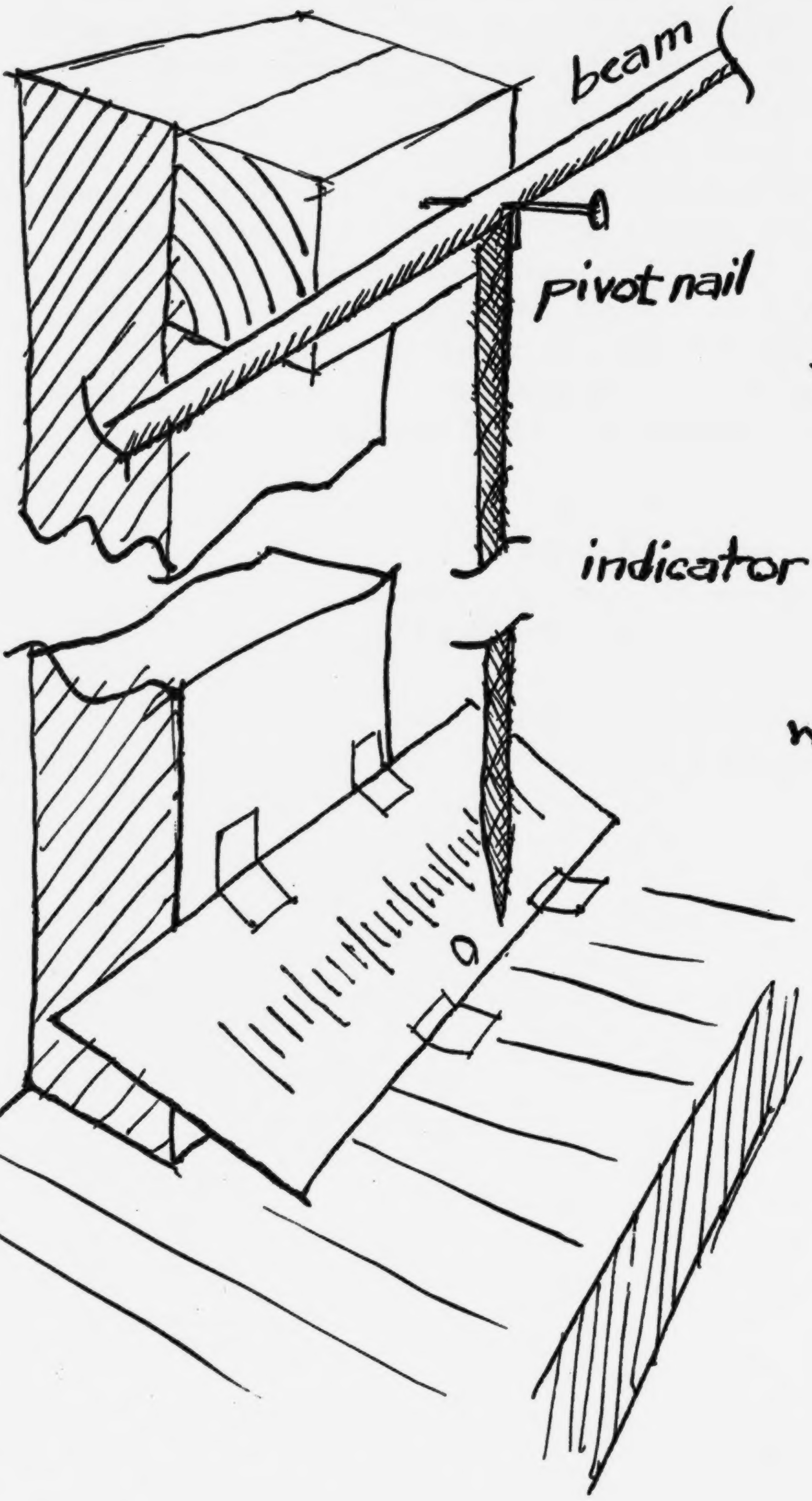

beam
pivot nail
indicator
0

fig. 6

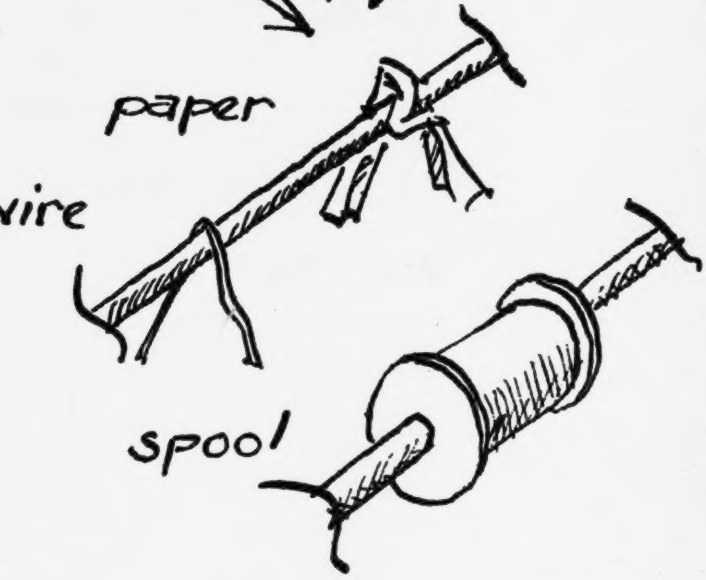

paper
wire
spool

fig. 7

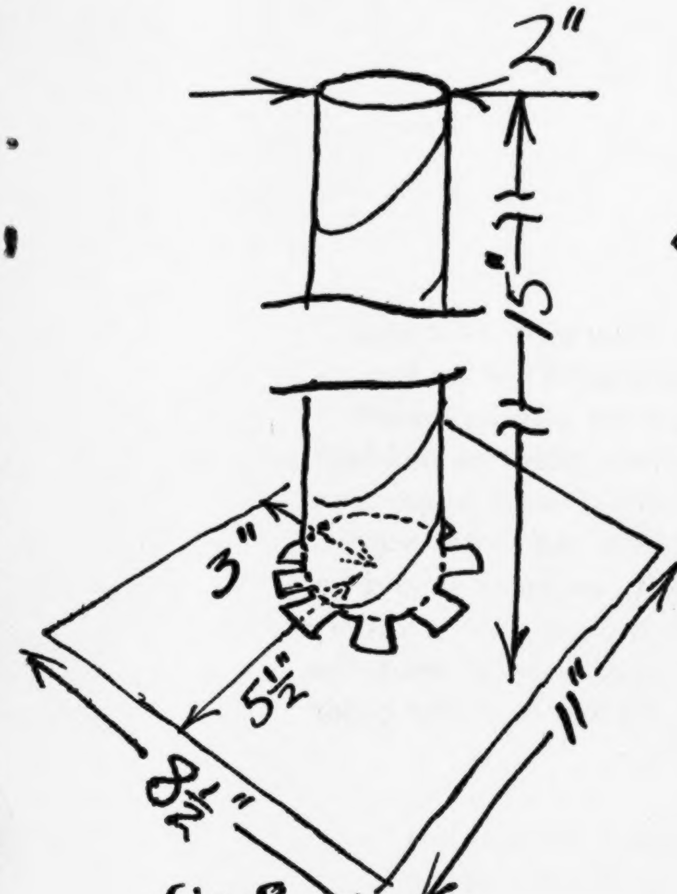

2"
15"
3"
5½"
8½"
11"

fig.8

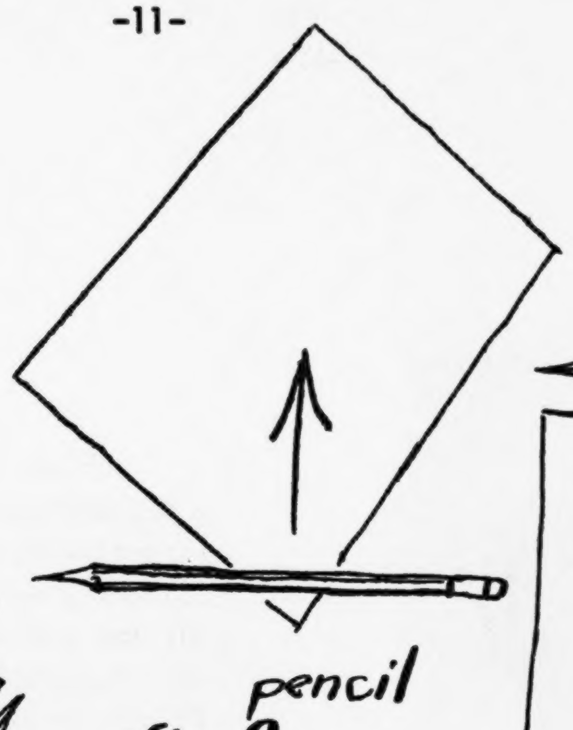


fig. 9

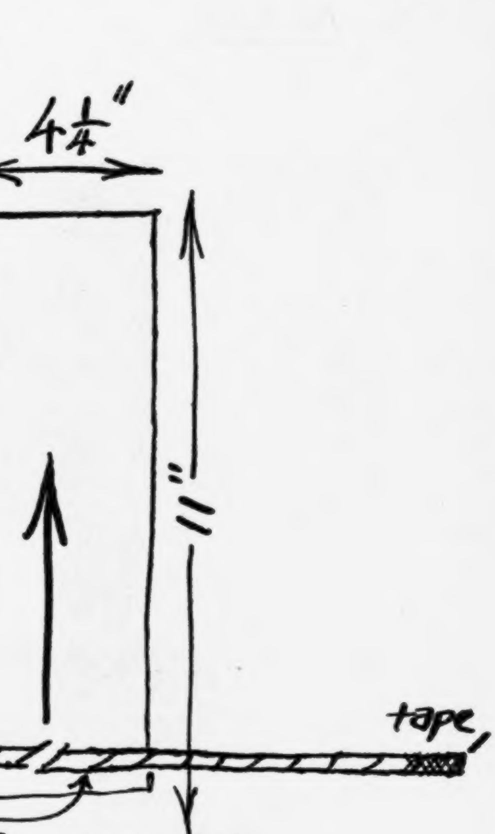

4¼"
11"
tape
tape
paper tubes

fig. 10

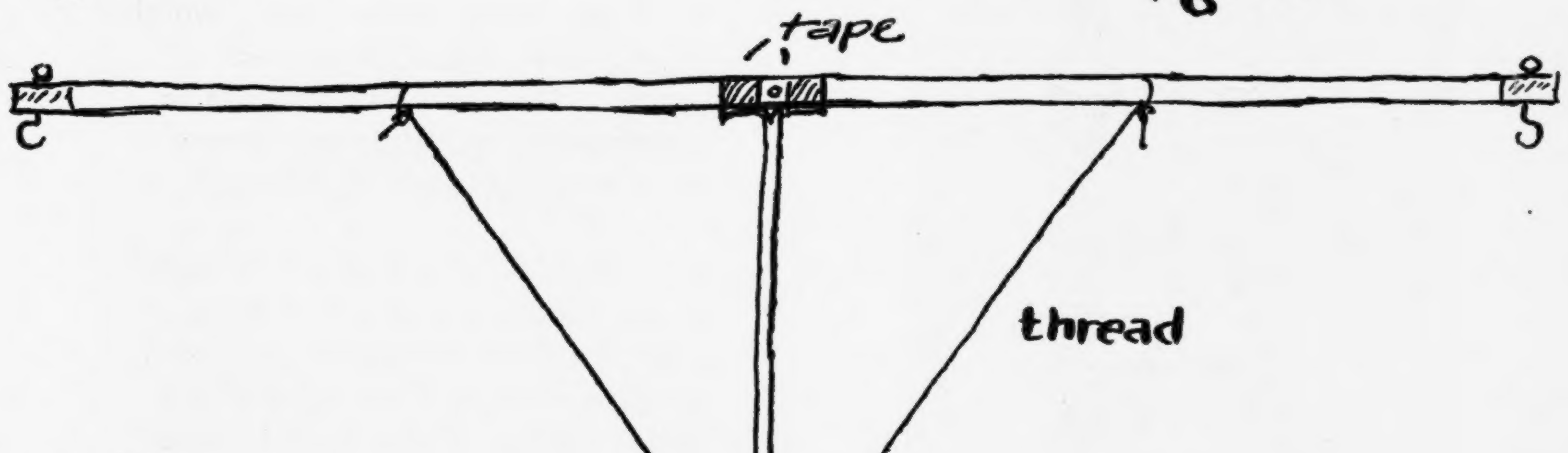

tape
thread
indicator

fig. 11

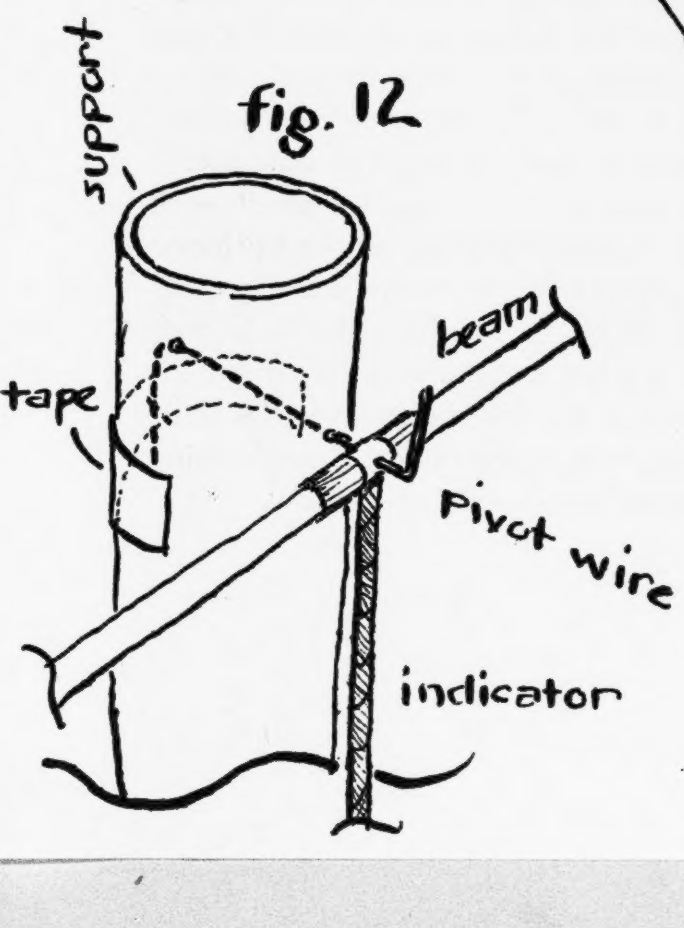

support
beam
tape
pivot wire
indicator

fig. 12

C. Air Pump.

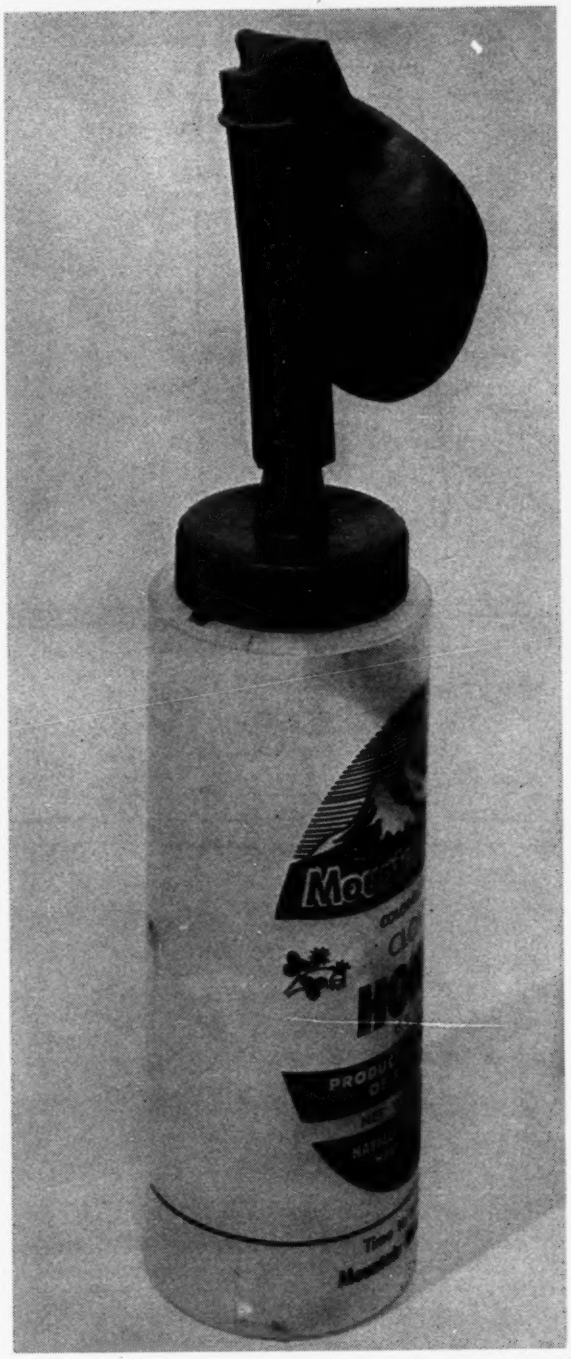


Plate 3.

Unless otherwise indicated, a toy balloon should not be inflated by blowing into it; breath is usually warmer than the ambient air and contains a large proportion of carbondioxide and water vapor. For this reason, balloons should be inflated with a pump. An ordinary bicycle-tire pump can be used; the cost of such a pump is on the order of $1.- to $2.-.

A cheaper, though less convenient, pump can be made from one of the plastic dispensers of catchup, relish, honey, etc., which have a screw cap with pointed nozzle. They can be purchased in supermarkets and elsewhere empty for 20¢ to 30¢ (Fig. 13; Plate 3).

We drill or punch a 1/4" hole in the middle of one side. If we want to inflate a balloon, we put it over the nozzle; if the neck of the balloon is too wide, we put a stopper with a hole over the nozzle and the balloon over the stopper. We put our thumb (preferably wet) over the hole and squeeze the bottle as far as possible. Then we pinch with two fingers the neck of the balloon to prevent the air from leaking out; we lift the thumb from the hole and let the bottle return to its normal shape. Put the thumb over the hole again and squeeze while unpinching the balloon neck, and so on.

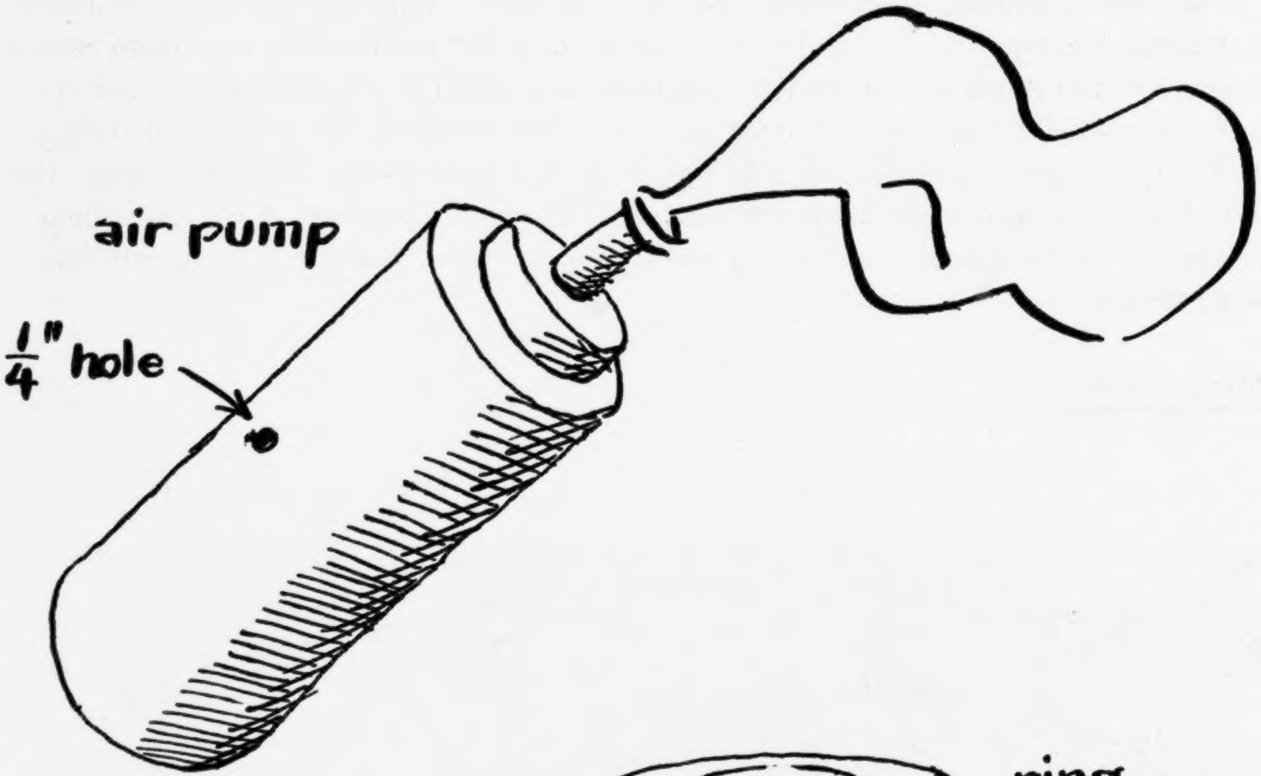

air pump
$\frac{1}{4}$" hole

fig. 13

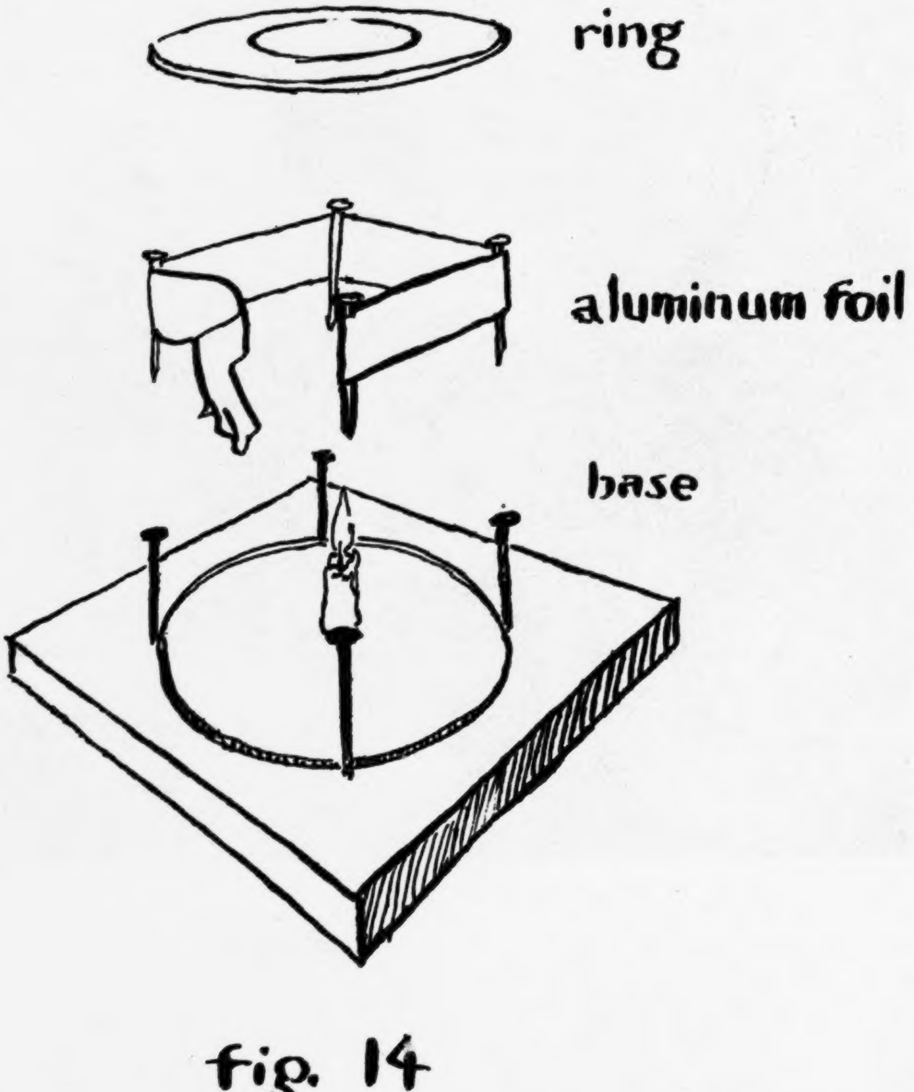

ring
aluminum foil
base

fig. 14

D. Smoke Source.

In several experiments a smoke source is needed. This represents no problem, if the instructor is a smoker, as smoke from tobacco is the most easily produced smoke. If the instructor and none of the students smokes, a cigarette can be lighted and its smoke accumulated for transfer into another container by using the pump illustrated on Plate 3. The cigarette is placed into one end of a short piece of rubber hose, the other end of which is put over the pump nozzle. Using the pump as a suction pump by reversing the process described in the preceding section, we can fill the plastic bottle with smoke.

E. Heating Stand

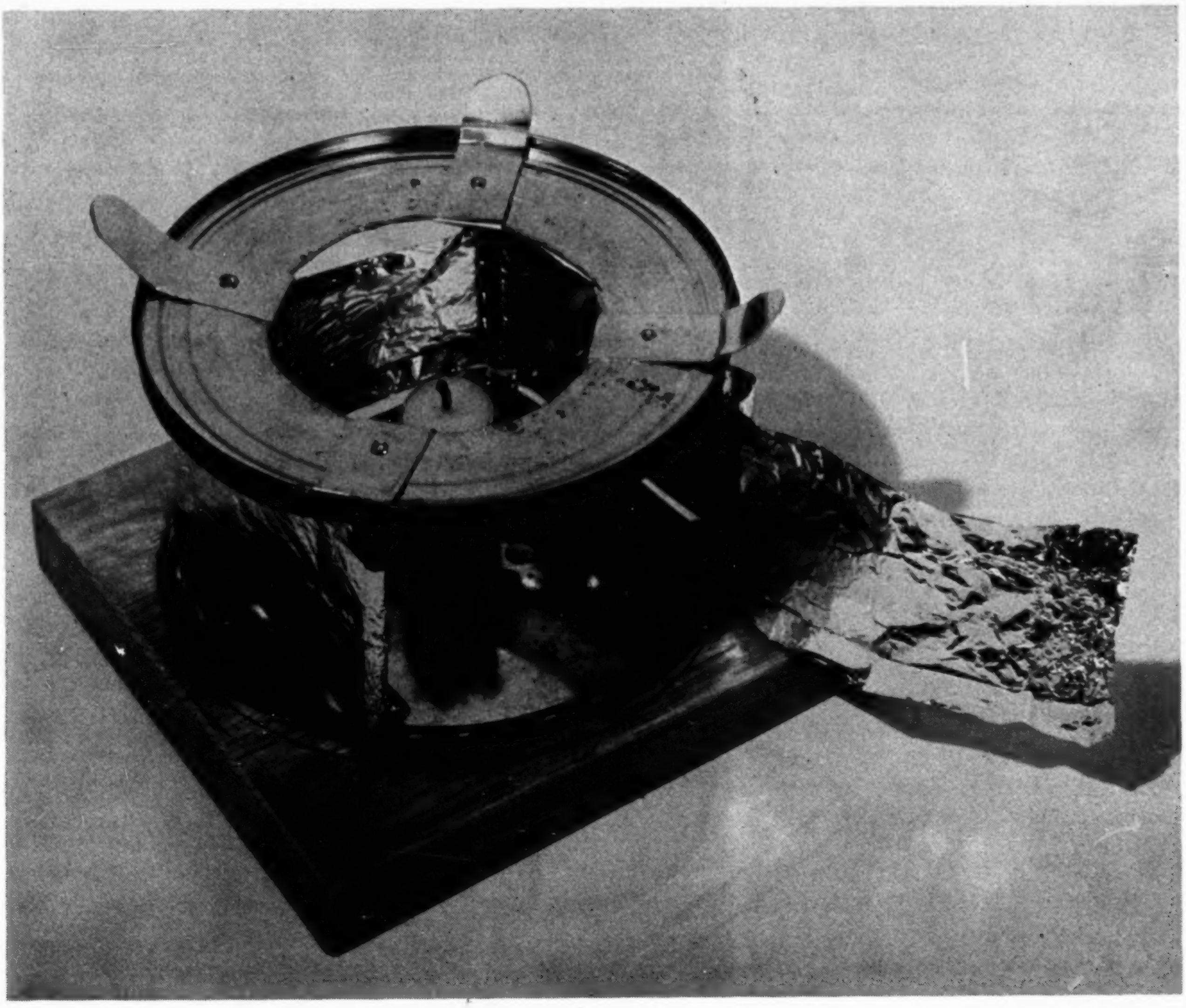


Plate 4.

If no stand for a heat source, such as a candle or Sterno Canned Heat, is available, one can easily be made with a piece of wood 3/4 x 5-1/2 x 5-1/2". The nails are so spaced that the can, to be heated, fits on the nailheads. A jar lid serves either to catch the candle drippings or as a trivet for the sterno can. If there is draft in the room, the candle flame can be steadied by a strip of aluminum foil, 2 x 15", wound around the four nails as in Fig. 14.

A disk cut out of the center of a coffee-tin lid will leave a ring which we can set on the nails to accommodate other cans of different sizes (Plate 4).

If one candle stub does not furnish enough heat, two or more can be used.

Material:
- Piece of wood, 3/4 x 5-1/2 x 5-1/2"
- Four nails 3 to 4" long
- One jar lid
- One strip of aluminum foil, 2 x 15"
- One or more candle stub, or canned heat.

Cost: 25¢

IV. DEMONSTRATION MODELS AND EXPERIMENTS

1. Extent of the Atmosphere; Its Penetration.

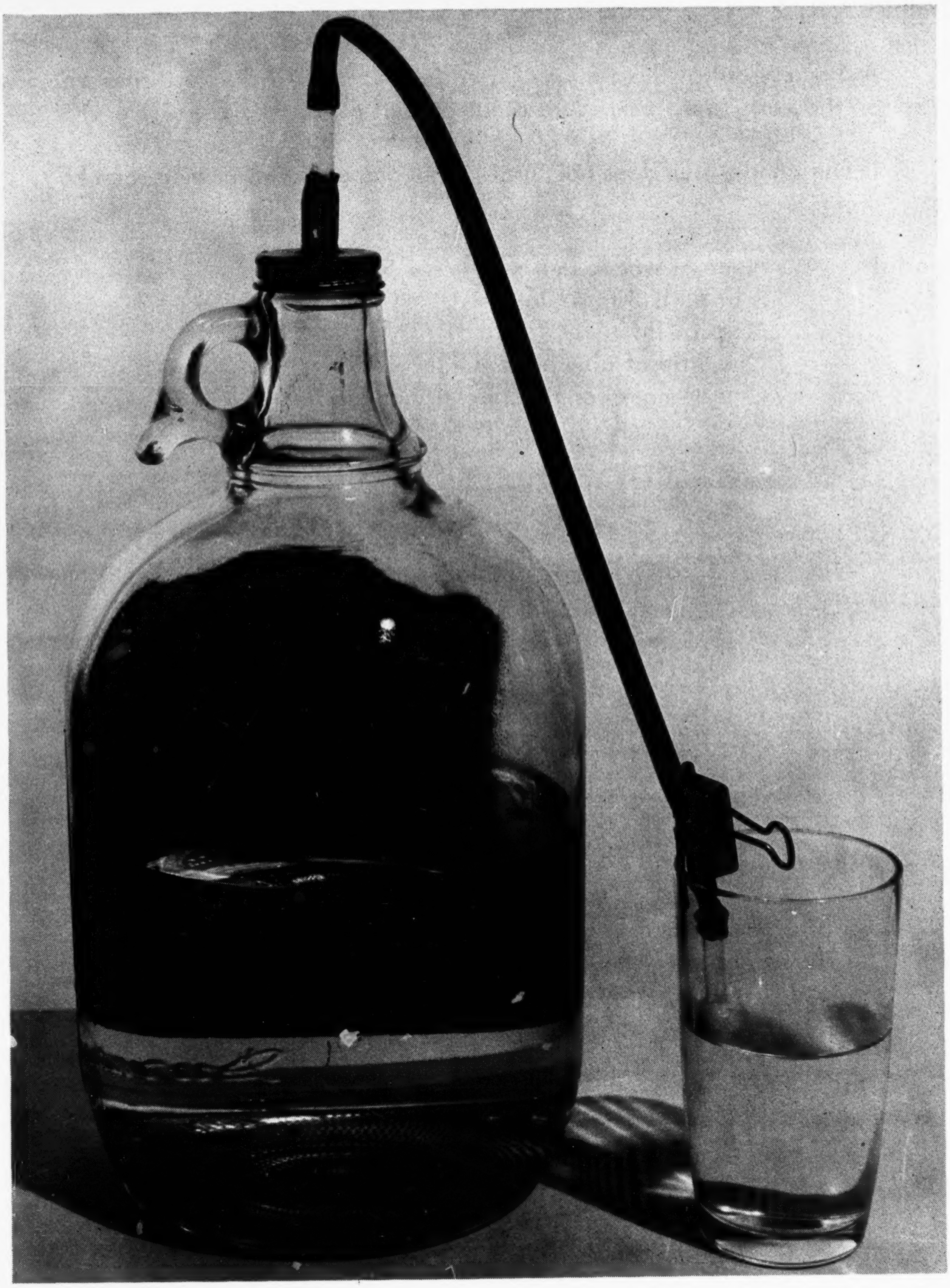


Plate 5.

From triangulations of the height of aurora (northern lights) we know that the atmosphere extends to at least 800 miles above the earth's surface. Of course, the density of the air, even at 200 miles, is so low that it is less than that of the best vacuum we can make in the laboratory.

As regards the lower boundary of the atmosphere, we generally say that the atmosphere starts at the surface of the earth. Actually, we can demonstrate that air penetrates the top layers of soil, water, and snow.

a) Fill a tumbler or small glass jar with very cold water from a tap and let it stand for half an hour or so. What do you observe?

b) Put a handful of soil or sand into a jar 3/4 filled with water; it may be necessary to tilt the jar back and forth a few times to produce the effect. What do you observe?

c) If snow is available, put a small snowball in a jar with water and hold the snowball under water. What do you observe as the snow melts?

d) We can show that air can be dissolved in water. We fill a gallon glass jug half full with water and let it stand for one to two hours to equalize any temperature difference between the water and the air above it. Then we close the jug air-tight with a stopper through which a hole has been drilled and a piece of glass or metal tubing (eye dropper will do) has been inserted. (For alternate method see Experiment 18.) A 12" piece of rubber or plastic hose is pushed over the tubing; another glass tubing (eye dropper) is put on the other end of the hose. We now pinch the hose shut and vigorously slosh the water around in the jug for a minute or two. We must avoid warming the jug with our hands. Then we insert the glass tubing into a tumbler (or small glass jar) with water, as in Plate 5 and unpinch the hose. What happens and why?

Material:
- One gallon jug.
- One stopper.
- Two eye-dropper glass tubings.
- 12" of rubber or plastic hose to fit the glass tubing.
- One tumbler or small glass jar.
- Water, soil, and snow (if available).

Cost: 30¢

2. Density Difference Between Hot and Cold Air.

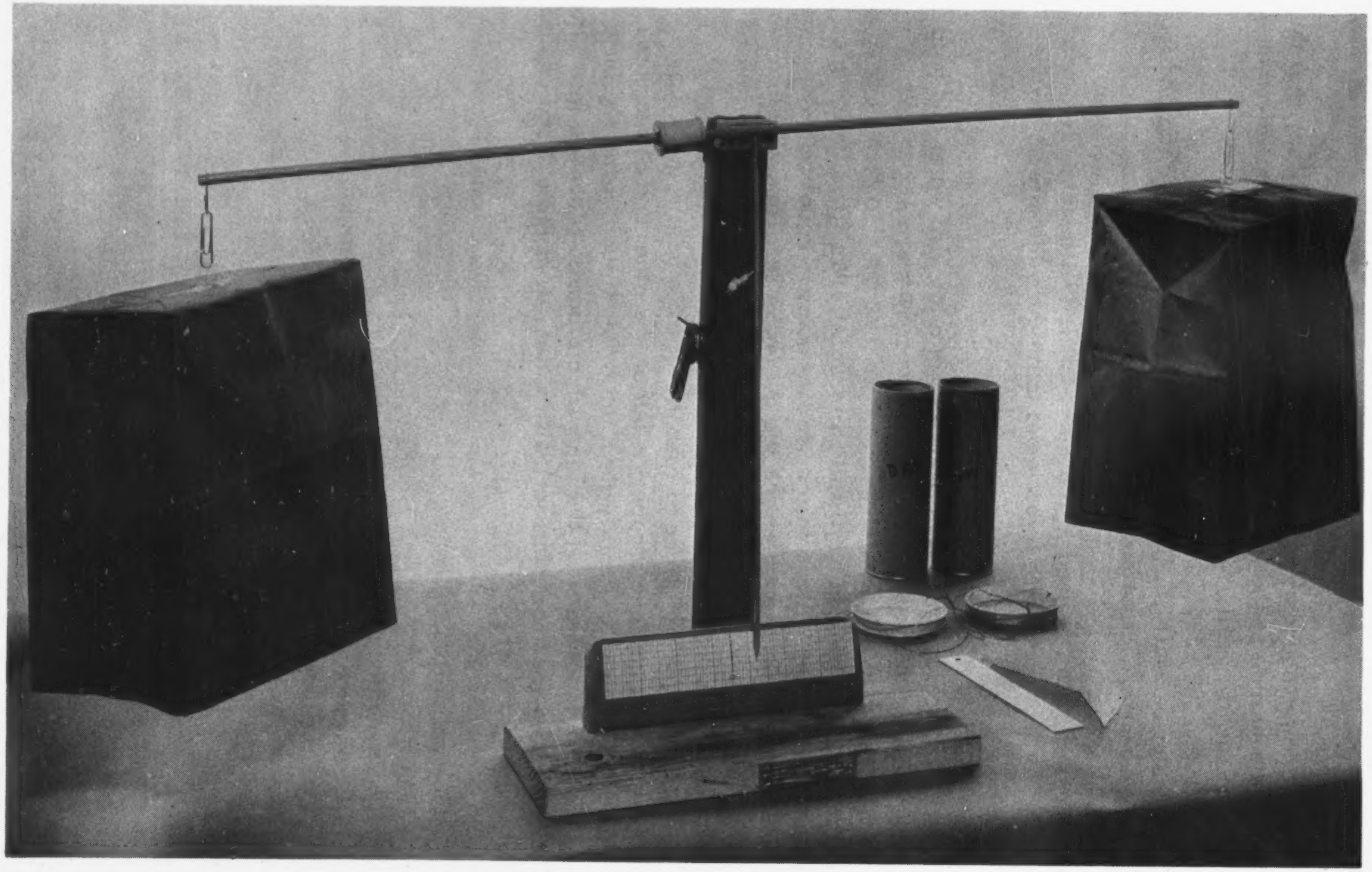


Plate 6.

Density of air is a function of temperature and pressure. To show the effect of temperature, we keep the pressure of a volume of air constant and the same as that of the ambient air.

a) By means of scotch tape (see Plate 6) we hang two paper bags of the same size upside down on a balance (see Section III.B). To keep the bags open, we fold the rims of the open ends outward. After we established equilibrium by means of a rider, we hold a small candle for half a minute under the middle of one of the bags, 3 to 4" away from it, being very careful not to set the bag on fire. We note almost immediately that this bag apparently becomes lighter than the other one. But watching a flame, we see a strong updraft rising from it. 1. Could the observed effect be due to the bag being lifted by the updraft? Inflate a toy balloon, hold the nozzle under the bag, and let a jet of air into it. 2. What is the difference between the effect of the candle and that of the air jet?

The combustion products of the candle are chiefly carbon dioxide and water vapor. 3. Which of these gases is lighter (less dense) than air? 4. Could it be that the lighter gas makes the bag buoyant? 5. How can we modify the experiment to eliminate this possibility? (Hint: Use a sheet of aluminum foil which is larger than the area of the bag opening). Try the modification. 6. Does the result of the modified experiment warrant the conclusion that hot air is, indeed, less dense than cold air?

b) Turn on a 100 to 150 watt lightbulb and hold it about 2" from the bag for two minutes, first at the bottom; then repeat the experiment holding the bulb at the side, and finally at the top of the bag. 7. Does the bag with the warmed air become lighter? Does it make much difference how the air is warmed?

Material:
- One balance
- Two medium sized paper bags
- One toy balloon
- One candle
- One sheet of aluminum foil, about 12 x 12"
- One 100 to 200 watt light source
- Scotch tape

Cost: 10¢

3. Weight and Pressure of Air; Pressure Gradient.

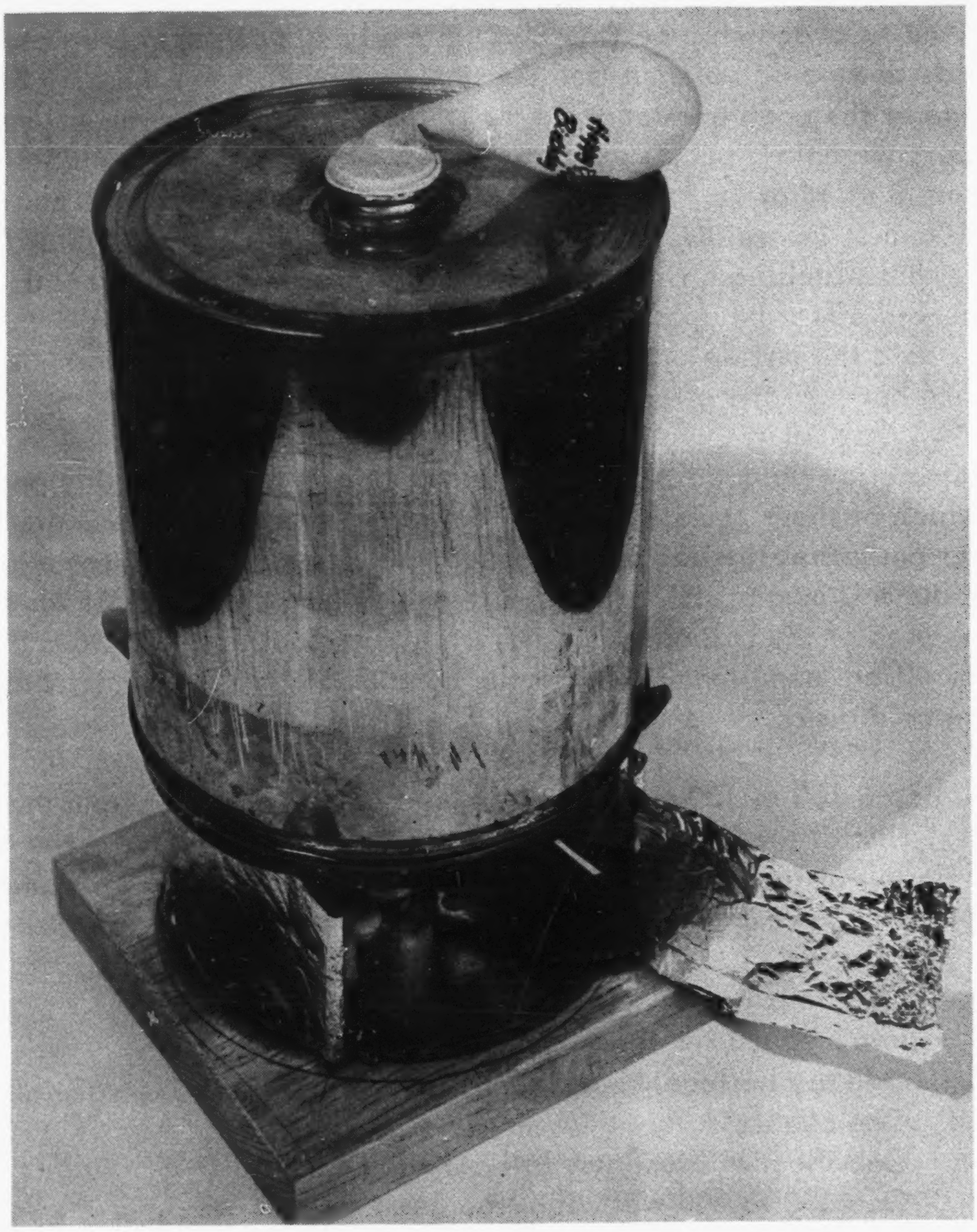


Plate 7.

The weight of the air on a unit area is the pressure of the air. At sea level, this amounts to roughly 14.7 pounds per square inch. The difference in air pressure over a unit horizontal distance is called pressure gradient.

a) We can demonstrate the weight of air by hanging two empty toy balloons on a balance (Section III, B); on one side we also hang a piece of string or rubber band with which we later tie the balloon after inflation. We establish equilibrium with a rider; then remove one balloon, inflate it, tie it, and hang it back on the balance. 1. What do you observe?

b) There are several ways of demonstrating the pressure of air. Immerse an empty tumbler or small glass jar upside-down into a bucket with water. 2. Why does the water not fill the glass? Why does a little water rise into the glass? Now we fill the glass to the very top with water, cover it with a sheet of stiff paper, and turn it quickly upside-down while holding the paper. 3. Why does the water not run out? We can also immerse a drinking straw into water, close one end by pressing a finger over the opening, and withdraw the straw; no water will run out of the straw. 4. Why do we need a piece of paper to hold the water in the tumbler but none to hold it in the straw?

c) For a more dramatic way to show the pressure of the air we need an empty tin can with screw top, such as the cans in which liquid detergents are sold. The screw cap must fit airtight. Caution: If an empty gasoline or oil can is used, or any can in which inflammable material was stored, these must first be thoroughly cleaned. We pour water into the can, just enough to cover the bottom of it, and heat the can over a candle or other heat source, until the water starts boiling; we then remove the can from the heat source and quickly put the screw cap on airtight. 5. What happens as the can cools? Why does this happen? Hint: The initial heating process and the conversion of the water into water vapor caused the air in the can to expand.

d) The expansion of air, when heated, can be demonstrated by means of a second can with a narrow neck; no water is needed in the can this time. The nozzle of a toy balloon is pulled over the neck of the can, if necessary with the aid of a stopper. The can is then heated over a candle (see Plate 7). 6. Why does the heated air go into the balloon? 7. Why does the air stream out of an inflated balloon when the balloon is opened? (Explain in terms of pressure gradient.) How is this phenomenon related to the cause of wind?

Materials:
One balance
Two toy balloons
One bucket or large container
One piece of stiff paper
One tumbler or small glass jar
One drinking straw
One tin can or canister with screw cap
One tin can with narrow neck
One candle or other heat source
Water.

Cost: 10¢

4. Oxygen Content of Air.

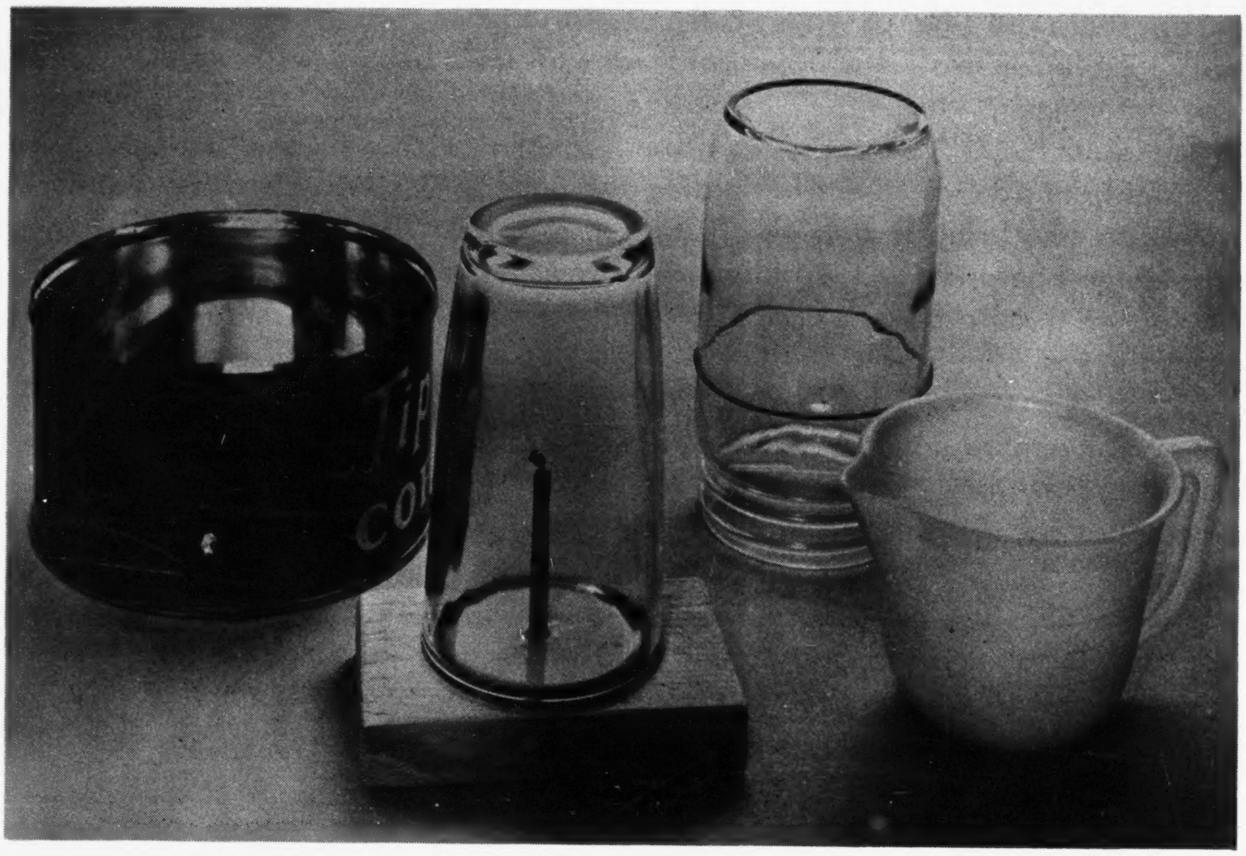


Plate 8.

Oxygen is consumed in combustion processes; this is utilized in determining the percent by volume of oxygen in air. We take two glass jars of different sizes, such as a jelly glass of 8 liquid oz. capacity and another jar of 16 liq. oz. capacity; the rims of these jars must fit a mason-jar lid (the screw ring is not used). We fasten half of a thin birthday candle (about 1" long 3/16" diameter or smaller) in the middle of the inside of a new mason-jar lid and light the candle. We quickly invert one of the jars over the lid and determine the time until the candle extinguishes. We repeat this twice and take an average of the times; but after each experiment we fill the jar to the top with water and empty it again, to make sure that we have fresh air in the jar for the next measurement. Then we do the same with the other jar. With a measuring cup, which is calibrated in liquid ounces, we determine the amount of water that we can fill into the jars to make them full to the brim. (If a graduated cylinder is available, the measurements can be made more accurately.) The volume occupied by the candle can be neglected. 1. Is the amount of oxygen, as

measured by the time of the candle-flame duration, the same in proportion to the measured volume of the two jars? How do you interpret this?
2. What may happen, if we do not fill the jar with fresh air?

Now we determine the amount of oxygen consumed by the flame. We light the candle, quickly put one of the jars upside-down on the lid lying on a block of wood (about 3/4 x 3 x 3"), and press the jar firmly down on the lid so that no air can escape. After the candle goes out, we slide the jar and lid from the block, still keeping the jar pressed on the lid, and immerse the jar (in the same position) in a bowl or large coffee tin filled with water. Under water we remove the lid and note that water enters the jar. When the jar has cooled, we lift it to a position in which the water level inside the jar is the same as outside and put a rubber band at that place as a marker (Fig. 15). Then we withdraw the jar, fill it to the marker, and measure the amount of water we have to add to make the jar again full to the brim. This amount divided by the total capacity of the jar furnishes the proportion of oxygen in the air. We repeat this measurement with the other jar.

3. What is the percent oxygen? 4. Why do we have to press the jar on the lid? (Try the experiment again without keeping jar and lid airtight). 5. Why do we have to let the air in the jar cool, and why do we have to have the water levels inside and outside the jar the same, before we determine the level of displacement of oxygen by water? 6. What other error sources are encountered in this experiment, that make it unlikely to get a good measurement of the amount of oxygen in air? The actual amount is 21%.

Material: One measuring cup, graduated in liq. oz.
One pint mason jar
One half-pint mason jar
One mason-jar lid (without screw ring)
One or two thin birthday candles
One coffee tin can or bowl
One rubber band
Water
Wood, 3/4 x 3 x 3"
Watch with second hand.

Cost: 25¢

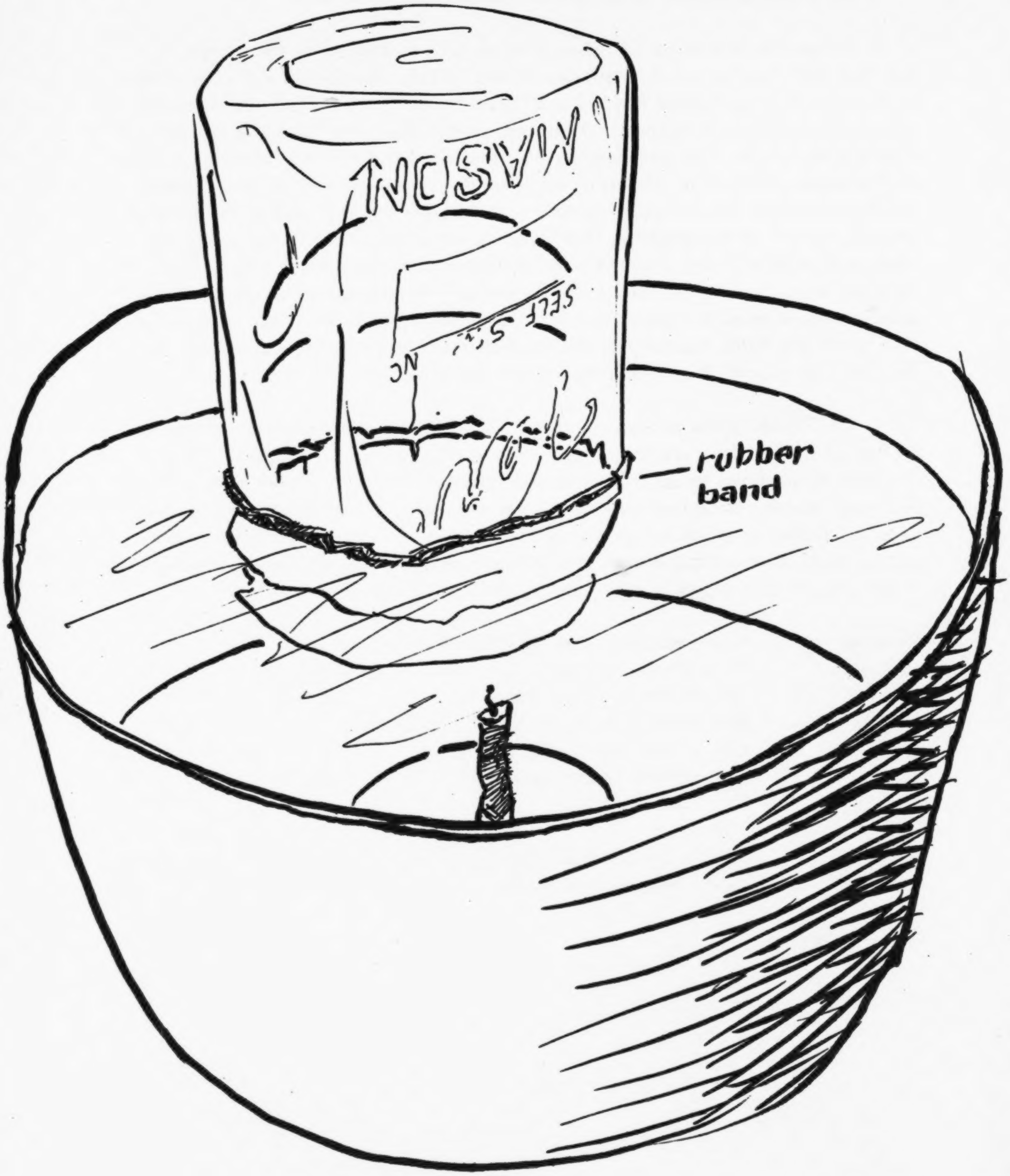

MASON
SELF SEAL NC
rubber band

fig. 15

5. The Sun and the Seasons.

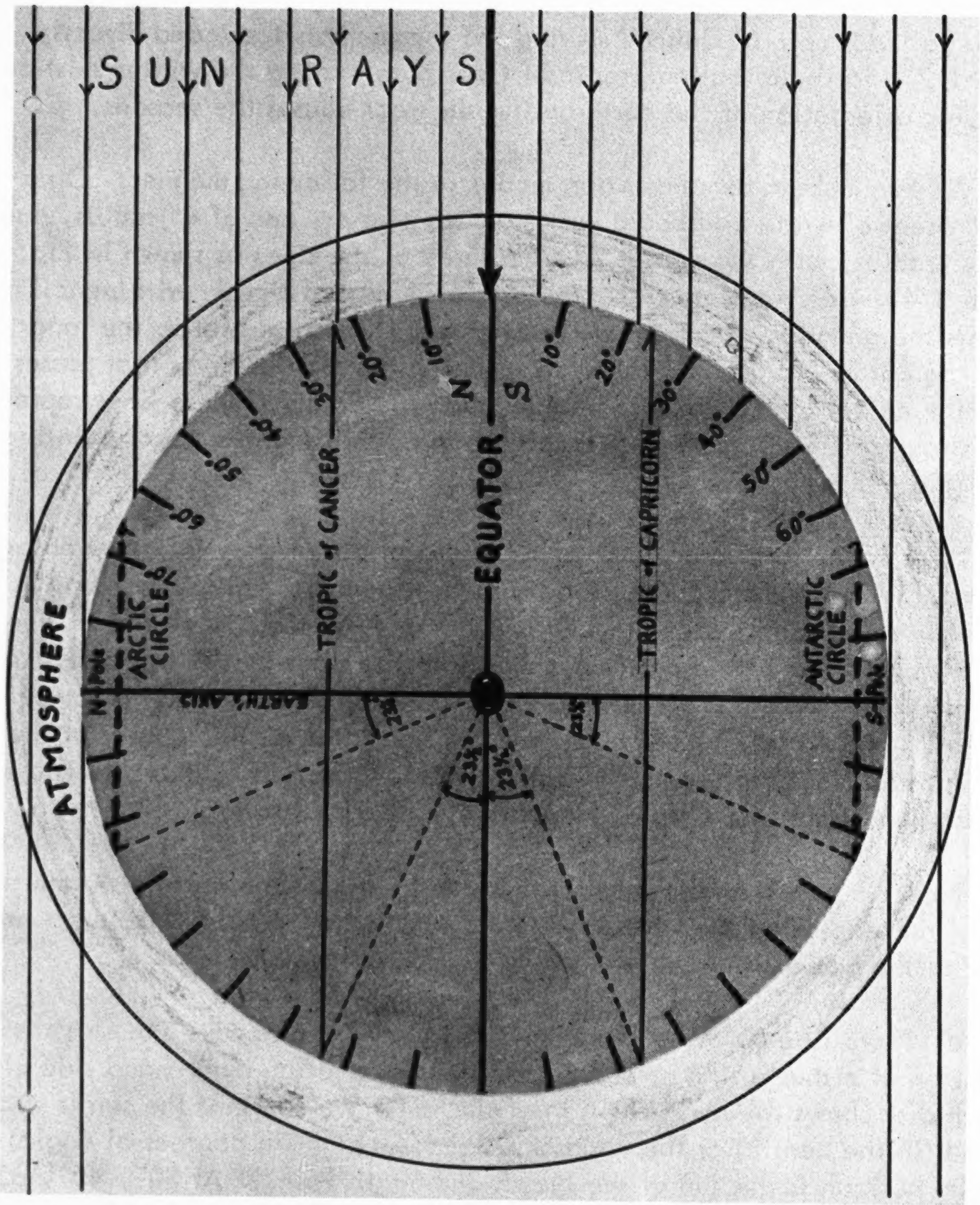

SUN RAYS
ATMOSPHERE
EQUATOR
TROPIC of CANCER
TROPIC of CAPRICORN
ARCTIC CIRCLE
ANTARCTIC CIRCLE
N Pole
S Pole
EARTH'S AXIS
N
S
10°
20°
30°
40°
50°
60°
23½°

Plate 9.

The angle between the earth's axis and the plane of the earth's orbit around the sun is 66-1/2°, or the angle between the earth's equatorial plane and that of its orbit is 23-1/2°. The orientation of the earth's axis relative to distant stars remains practically constant for long periods of time, so that the axis orientation relative to the sun changes, as the earth moves around its orbit. During the spring equinoxes (approximately 21 March) and the autumn equinoxes (approximately 23 September) the earth's axis is at right angles to the sun's rays. During the summer solstices (approx. 22 June) the northern half of the axis makes an angle of 90° – 23-1/2° with the sun's rays (the N-pole points toward the sun), whereas during the winter solstices (approx. 22 December) the axis makes an angle of 90° + 23-1/2° with the sun's rays (the N-pole points away from the sun). We can also say that, at noon, the sun is directly over the equator during the equinoxes, directly over 23-1/2°N latitude (called Tropic of Cancer) during the summer solstices, and directly over 23-1/2°S latitude (called Tropic of Capricorn) during the winter solstices. The varying orientation of the earth during the year causes the seasons.

We can make a demonstration model in the following manner. On a 10 x 12" sheet of white cardboard we draw two circles, one of 4" radius, one of 4-3/4" radius, with the center 5" from three of the sides as shown in Fig. 16. The 3/4"-wide ring formed by the circles is shaded lightly with pencil and represents the atmosphere. Then we draw straight lines parallel to the long sides of the cardboard at 1/2" intervals, making the middle line, that passes through the center of the circles, heavier than the others. These lines represent the sun's rays coming from the right; this we indicate by arrow heads pointing to the left (Fig. 17).

Now we cut a circular disk of 8" diameter out of grey (or other color) cardboard to represent a cross section through the earth. On this we draw a line for the equator through the center and another one, at right angles to it, for the earth's axis, and with a protractor mark the latitudes at 10° intervals around the periphery of the disk. We mark also latitudes 66-1/2° and 23-1/2° north and 23-1/2° and 66-1/2° south and draw lines parallel to the equator at these latitudes; these lines represent the Arctic Circle, Tropic of Cancer, Tropic of Capricorn, and Antarctic Circle, respectively (see illustration).

Now we punch small holes through the center of the earth disk and the center of the circles on the white cardboard and fasten the disk with a paper fastener to the board.

a) If we line up the equator with the heavy center ray, the earth is in the position of either spring or autumn equinoxes, and the right-hand side of the earth disk shows the noon position of the sun. We see that the sun is straight overhead (in the zenith) at the equator. 1. How high (in degrees of angle) above the horizon is the sun at the North and South Poles? At 30°, 45°, 60° latitudes? 2. How does the path length of the sun's rays through the atmosphere change with latitude? 3. How many latitude degrees does a bundle of sun's rays of 1/2" width cover at the equator? At 45° latitude? Near the pole? 4. What can you state about the solar radiation intensity at low, middle, and high latitudes, considering the answers to questions 2 and 3?

b) Now we turn the earth disk to the position it has during the summer solstices, i.e. we line up 23-1/2°N latitude with the center ray. 5. How high is the sun above the horizon at the equator? Is the sun there in the northern or southern sky? 6. How hish is the sun at the N-pole? S-pole? 7. What can you say about the day length north of the Arctic Circle? South of the Antarctic Circle? 8. Where is the sun at the zenith? 9. Between what angles does the sun's altitude vary along the Arctic Circle? Antarctic Circle? 10. What can you say about the radiation intensity at 45°N and S latitudes as compared to that during the equinoxes?

c) Finally, we turn the earth disk to the position it has during the winter solstices and answer again the questions 5 through 10, for this condition.

Material: One piece of white cardboard 10 x 12"
One piece of grey (or other color) cardboard 8 x 8"
One paper fastener
One protractor (used for drawing only)

Cost: 20¢

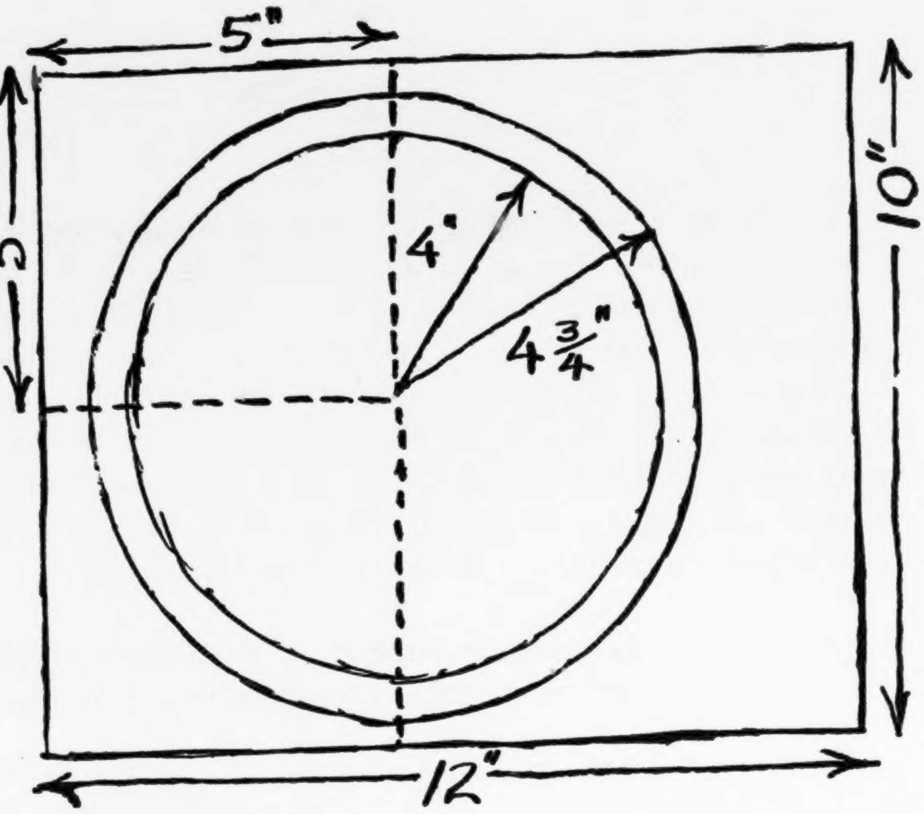

5"
5"
10"
4"
4 3/4"
12"

Fig. 16

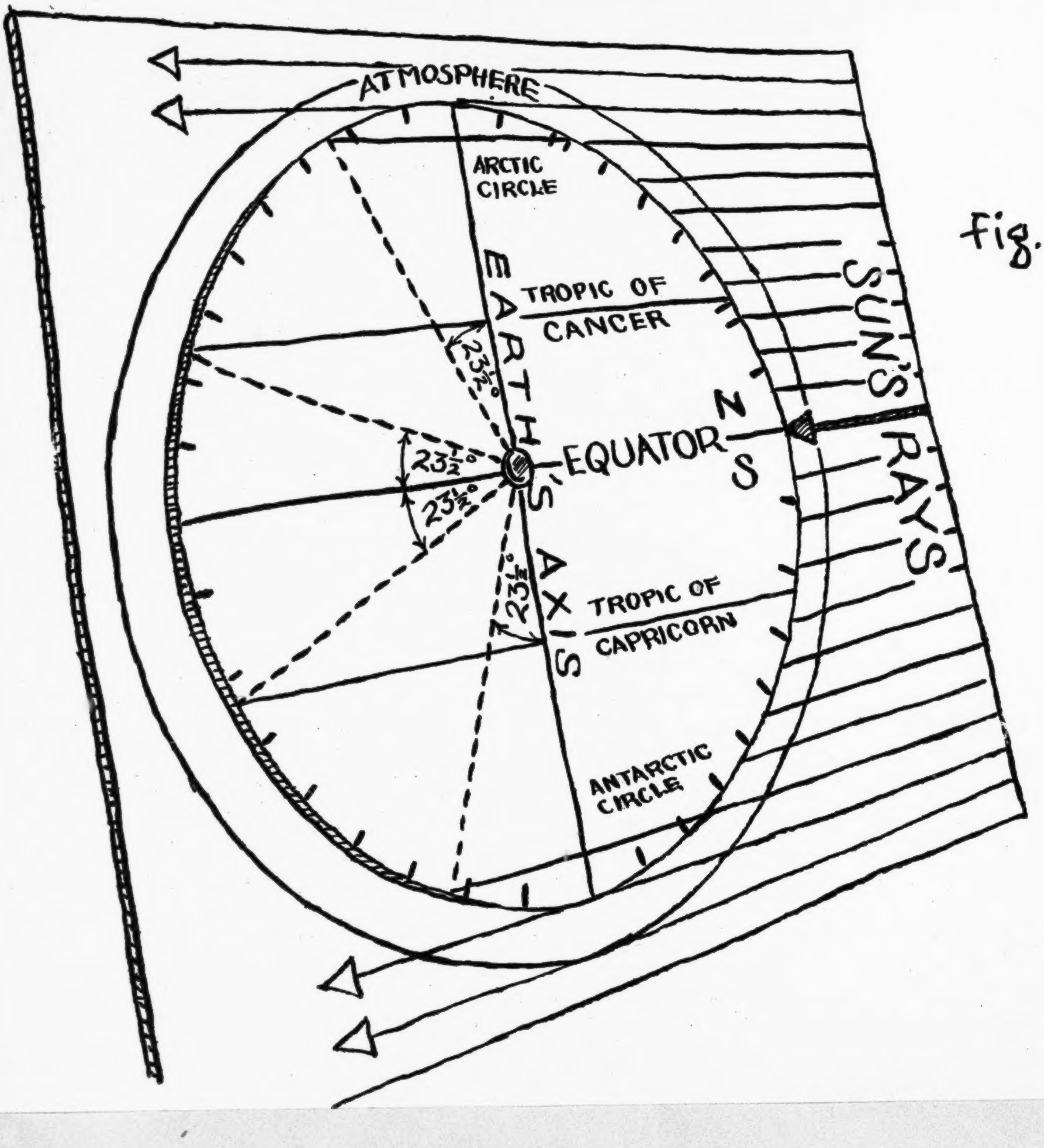

ATMOSPHERE
ARCTIC CIRCLE
TROPIC OF CANCER
EARTH'S AXIS
23½°
23½°
23½°
23½°
EQUATOR
N
S
SUN'S RAYS
TROPIC OF CAPRICORN
ANTARCTIC CIRCLE

Fig. 17

6. Relationship between Temperature, Dew Point, and Relative Humidity.

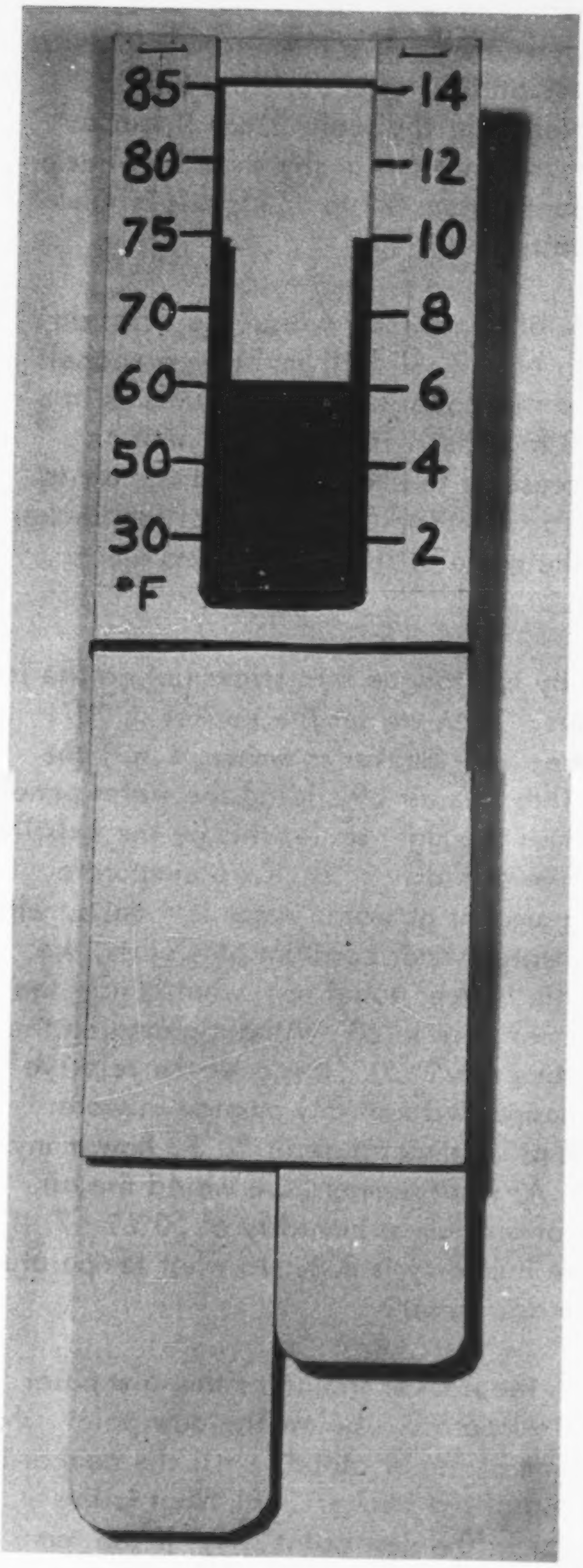


Plate 10.

Humidity refers to the amount of water vapor in the air. The highest amount of water vapor, that can be mixed with dry air, depends only on the temperature of the air. When air at any temperature contains this maximum amount of water vapor, it is said to be saturated; when it contains less, it is unsaturated. The amount of water vapor at saturation roughly doubles for a rise in temperature of 20°F, so that, e.g., saturated air at 70°F contains about twice as much water vapor than does saturated air at 50°F.

The ratio of the existing amount of water vapor to the maximum amount, that could be contained by the air at a given temperature, multiplied by 100, is the relative humidity in per cent. Another expression of the humidity in the air is the dew point. This is the temperature to which we would have to cool the air (without change in pressure), in order to make it saturated.

For demonstration of the relationship between temperature, dew point, and relative humidity, we cut four pieces of heavy white cardboard, each 3-1/2 x 11". Three of them are cut out as shown in Fig. 18 with the proper dimensions. Round off the corners of panels No. 2 and 3. From pieces cut away we make two strips 3-1/2 x 3/8" and paste them over one another on top of panel No. 1 along the edge. The hatched area of panel No. 2 is painted blue to represent water. The cut-out portion of panel No. 3 is painted with a black border, about 3/8" wide, as shown by the hatching in Fig. 18. On panel No. 4 we paint a black line along the bottom edge of the cut-out, about 1/8" wide with rounded corners as shaded in Fig. 18. Then we mark off a temperature scale on the left side of panel No. 4, according to Plate 10. The divisions are 3/4" apart and start 1/2" from the top edge. (Note that the scale is not linear as on a thermometer.) On the right side we mark divisions at the same level as on the left, but label them with the even numerals from "2" to "14"; this is the scale of water vapor amounts in arbitrary units.

Now we staple or glue the top edge of panel No. 4 onto the strips on panel No. 1. Then we lay panel No. 3 on No. 2, slide them between panels No. 1 and 4, and put a rubber band around the model below the scales as in Fig. 19. The black margin of panel No. 3 together with the black line on panel No. 4 appears as a beaker which represents the "capacity" of the air to hold water in vapor form (the blue panel No. 2). The upper edge of the beaker is set at the air temperature and reads on the scale at the right the maximum amount of water vapor at that temperature.

Let us slide the "water panel" out by the tongue that sticks out on the left side of the bottom, till the water disappears. Then we set the beaker at 70°F (by the right-hand tongue) and hold it there. The beaker is empty, i.e., the air is dry. We now evaporate some water into this air by sliding the water panel up till the water edge is even with the "2" on the right scale; this be the existing water vapor amount. 1) What is the relative humidity? 2) If we evaporate more water into the air so that the existing amount of water vapor is 4 units, what is the relative humidity? 3) Keeping the water vapor constant at 4 units, we raise the temperature to 75°F (by pushing the beaker panel up); what is now the relative humidity? 4) If we lower the temperature to 60° without changing the water vapor content, what is the relative humidity? 5) How does the relative humidity change, when the temperature changes without any change in water vapor? 6) If the relative humidity is 50% at a temperature of 80°F, how many units of water vapor does the air contain? At what temperature would the air contain 1/3 of this amount of water vapor at a relative humidity of 50%? 7) If the air temperature is 75°F and the relative humidity is 80%, to what temperature would we have to cool the air to reach the dew point?

It is evident that the water level in the beaker indicates the dew point on the temperature scale. If we lower the temperature below the dew point, the water above the beaker condenses out in form of fog or cloud, until the beaker is just full (we lower the water level to the top of the beaker). 8) What is the relative humidity if the temperature is equal to the dew point? 9) If the temperature is 70°F and the dew point is 60°F, what is the relative humidity?

10) If the dew point is 65°F and the relative humidity is 50%, what is the temperature?

Note that all these values are very rough approximations, because the scales are greatly simplified.

Material: Four pieces of white cardboard, each 3-1/2 x 11"
Black ink
Blue ink
Glue
Rubber band.

Cost: 10¢

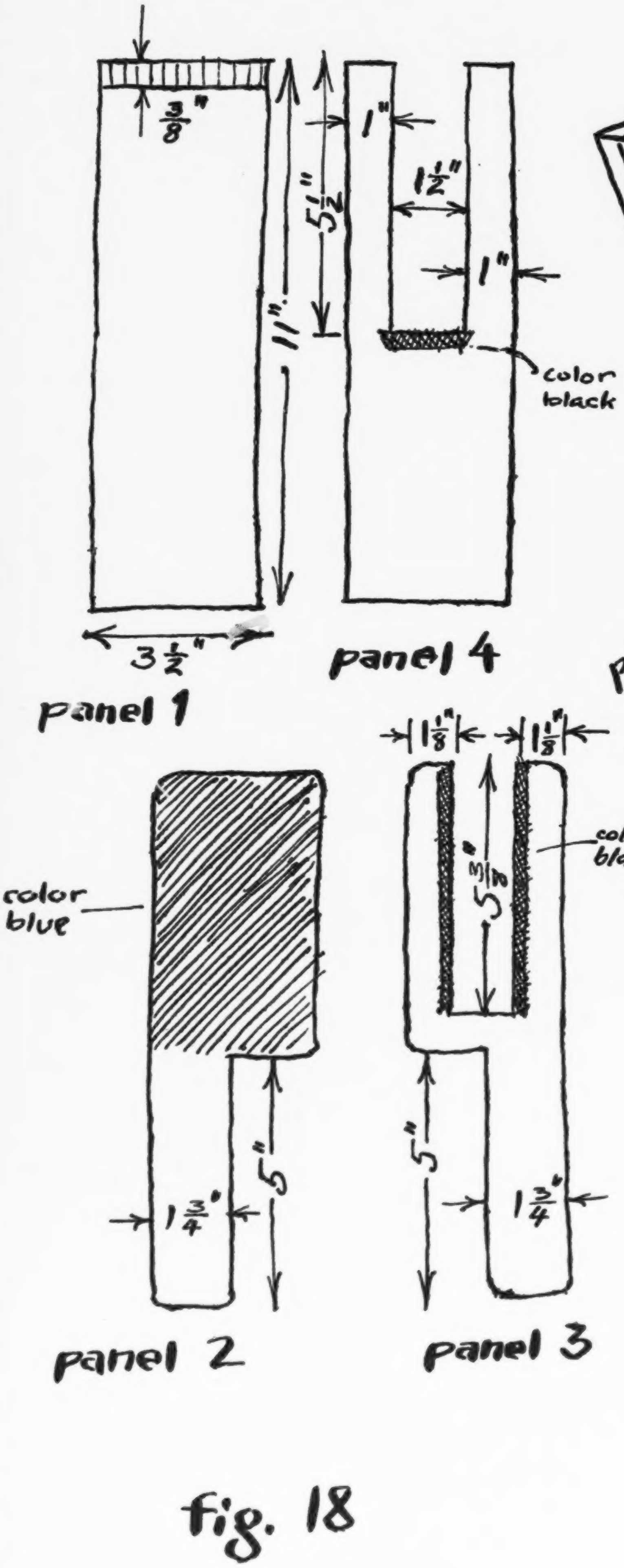

3/8"
11"
5½"
1"
1½"
1"
color black
3½"
panel 4
panel 1
1⅛"
1⅛"
color blue
5 3/16"
color black
1¾"
5"
5"
1¾"
panel 2
panel 3

fig. 18

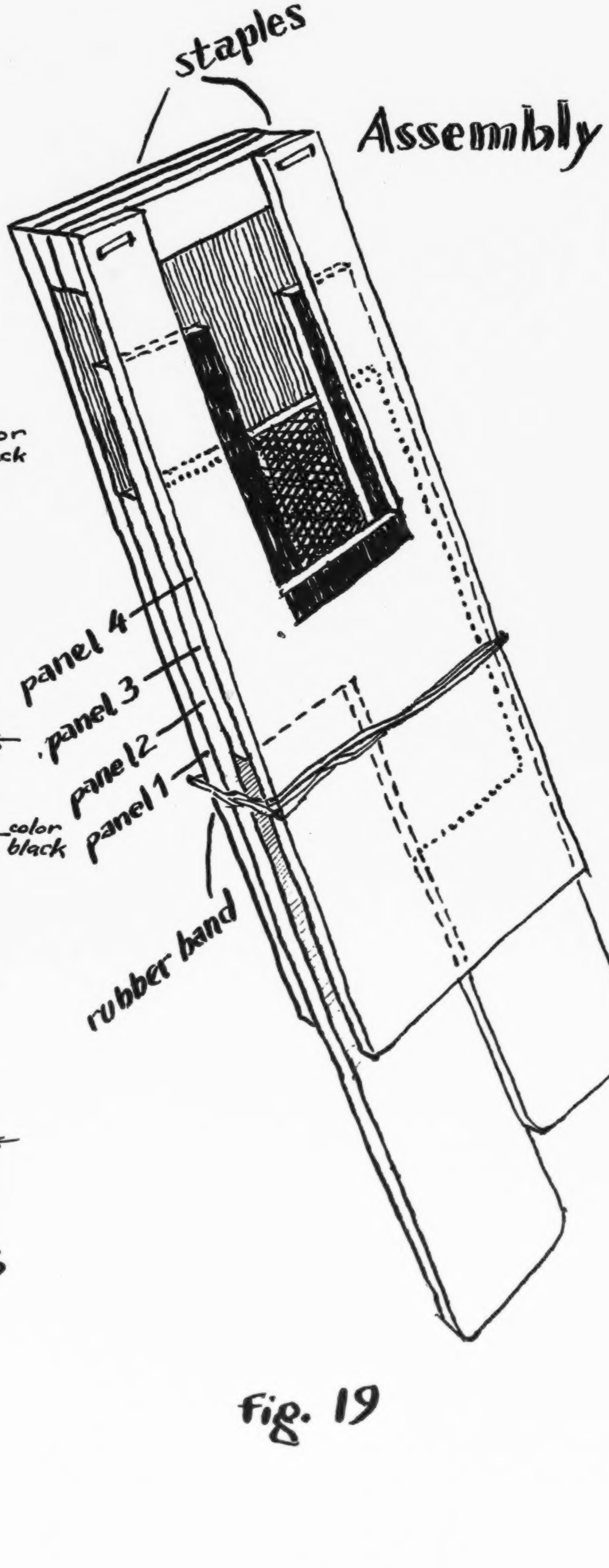

staples
Assembly
panel 4
panel 3
panel 2
panel 1
rubber band

fig. 19

7. Dew and Frost.

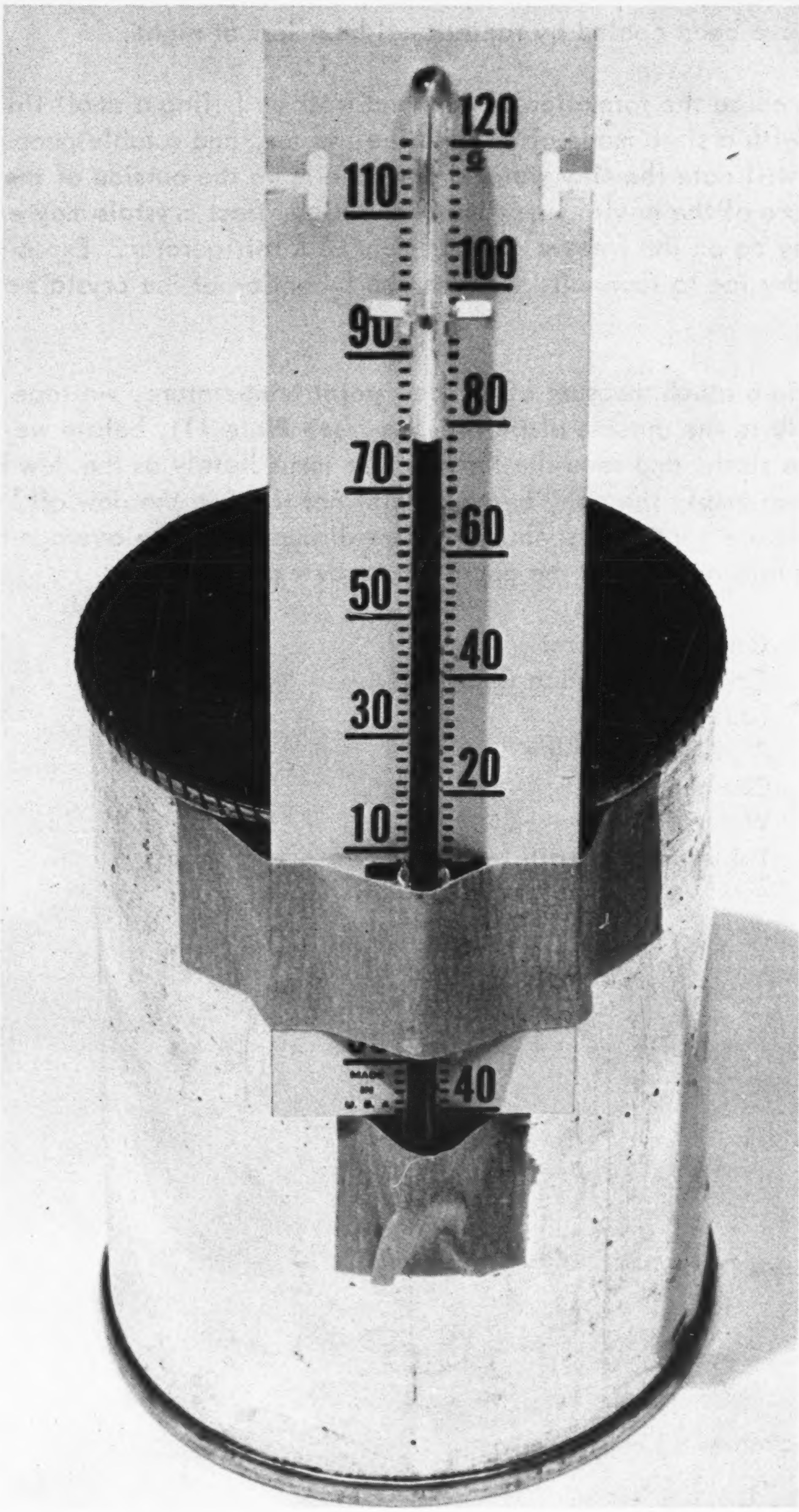

120
110
100
90
80
70
60
50
40
30
20
10
MADE IN U.S.A.
40

Plate 11.

Condensation takes place when the air is cooled below its dew point. In nature, the formation of dew, or frost if the temperature is low enough, occurs usually when the air is cooled by contact with objects on the earth, which in turn have been cooled by radiational heat loss at night.

We can cause the formation of dew and frost by filling a small tin can of shiny metal with a slush made of crushed ice, water, and a tablespoon of salt. We soon will note the tiny water droplets form on the outside of the can. If the temperature of the environment is not too high, frost crystals may eventually form as they do on the freezer compartment of a refrigerator. Exposing a small piece of dry ice to room air, we note the formation of ice crystals on the dry ice.

To obtain a rough measure of the dew point temperature, we tape a thermometer bulb to the outside of the tin can, (see Plate 11), before we fill the can with the slush, and read the temperature immediately as the dew begins to form. We then empty the can, being careful not to wipe the dew off, and read the temperature again, as soon as the dew disappears. The average between the two temperature readings is the approximate dew point.

Material:
One thermometer,
One shiny tin can (small)
Tape
A piece of dry ice
Crushed ice
Water
Tablespoon of salt.

Cost: 40¢

8. Relative Humidity.

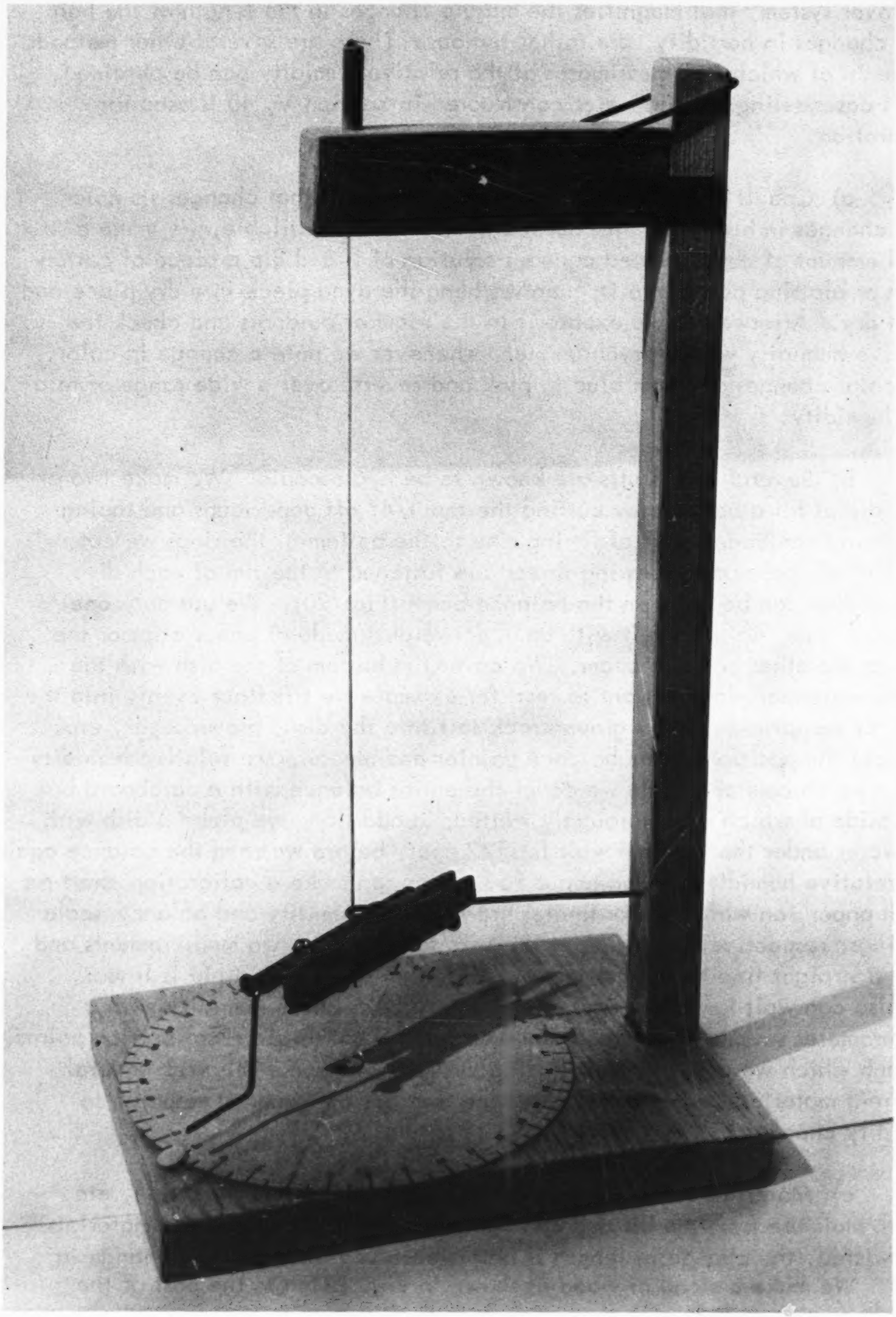


Plate 12.

The most frequently used instrument for direct measurement of relative humidity is the hair hygrometer. However, home-made hair hygrometers are not satisfactory; moreover, the preparation of the hair and the construction of the lever system, that magnifies the minute changes in the length of the hair with changes in humidity, are rather tedious. There are several other methods by means of which rough estimates of the relative humidity can be obtained. In all cases,a sling-psychrometer constructed in Section V, 40 is used for calibration.

a) Cobalt chloride is a hygroscopic chemical that changes its color with changes in humidity. If cobalt chloride salt is available, we make a small amount of concentrated aqueous solution of it and dip a piece of cotton cloth or blotting paper into it; then we hang the dyed piece in a dry place and let it dry. Afterwards, we expose it in the room or outdoors and check the relative humidity with a psychrometer, whenever we note a change in color. The color changes are from blue to pink and reverse over a wide range of relative humidity.

b) Several food stuffs are known to be hygroscopic. We make two or more dishes for a balance by cutting the top 1/4" off paper cups and taping or glueing cardboard disks of fitting size to the bottom of the rings we cut. Three 6" pieces of stout sewing thread are fastened to the rim of each dish, so that they can be hung on the balance beam (Fig. 20). We use only one dish at a time, balancing it with counter-weights made of paper clips or the like on the other balance beam. We cover the bottom of the dish with the hygroscopic material we want to test; for example we sift flour evenly into the dish, or we sprinkle finely ground rock salt into the dish, brown sugar, etc. We note the position of the balance pointer and measure the relative humidity with a psychrometer. Then we cover the entire balance with a cardboard box, the inside of which was thoroughly wetted; in addition, we place a dish with hot water under the box and wait for 1/2 hour, before we read the balance again. The relative humidity is then about 95%. We can make a calibration chart on graph paper, on which the ordinates are relative humidity and balance-scale readings, respectively. We enter the two points of our two measurements and draw a straight line through them, assuming that the relationship is linear. We also can wait for a few days and measure the relative humidity with a psychrometer several times each day and thereby obtain more calibration points, through which we draw the best-fitting curve. We repeat this with several different materials and find the substance that has the greatest response to humidity changes.

c) Materials such as gut string, wool thread, wrapping twine, etc. absorb moisture from the air and change their lengths. Since these materials are twisted, the change in length is better observed through their change in twist. We make a stand of wood as shown in Fig. 21. On the post of the stand we make a suspension beam, 3/4 x 1-1/2 x 4-1/2", which is moveable up and down for adjustment to different lengths of the substances we wish to test. On each side of the beam a strip of tin-can metal 1/2 x 2" is nailed as guides; a 6" piece of cloth-hanger wire is bent into U-shape around the post of the stand, the ends bent at right angles and inserted into the suspension beam as shown in Fig. 22. This wire holds the beam in place by friction. About 1/2" from the free end of the beam, a 1/4" hole is drilled from the top. A 2" piece of 1/4" dowel rod is slotted lengthwise with a saw and one end slightly tapered, so that, when we have a string inserted into the slot and the plug inserted into the hole of the suspension beam, the string is held fast by the plug (Fig. 23).

A piece of stiff wire, 6" long, is bent at one end into a small loop and with the other end stuck into the post about 2" above the base board, so that the loop is straight under the hole of the suspension beam. We cut a circular disk of 3" radius out of cardboard and make scale divisions along the rim for every 5 degrees, numbering every 10 degrees, with numbers from "0" to "35". The disk is fastened with a thumbtack through the center onto the base board in a plumb line under the hole in the suspension beam and the wire loop (Fig. 24; Plate 12).

Then we make a pointer out of a clothes pin, to which we cement a piece of stiff wire, about 3 to 4" long, bent in the shape indicated in Fig. 25. The string to be tested is clamped into the pin; to stretch the string, we wire or tape on each side of the pin two or more heavy 3" nails, so that the total weight is at least 1 oz.

We get a piece of broken gut string from a violin, viola, or guitar, making sure that the string is not made of nylon. We cut the kinked or curled portion off the string and use only the straight portion. The string is clamped in the plug at the top and the pin at the bottom; the pin should hang horizontal and the pointer should be about 1/4" above the scale. We let the instrument stand for a few hours, so that the string is stretched to its equilibrium length. Then we take a reading of the scale and a relative humidity reading with a psychrometer. Using a wet box as in section b), we determine the point of 95% relative humidity, and make a calibration chart for this instrument. We repeat this for several different materials such as wrapping cord and wool thread. Some of the materials have a rather large response to changes in humidity, so that the pointer may turn more than a full circle; in this case, we have to shorten the string. For example, a gut string should be less than 10" long.

Material: a) Half a teaspoon full of cobalt chloride
White cotton cloth or white blotting paper, 2 x 6"
Water

Material: b) One balance
Two or more paper cups
One yard of heavy sewing thread
Two or more cardboard disks, about 3" diameter
Tape or glue
Small amounts of flour, brown sugar, rock salt, etc.
Big cardboard box to fit over balance
Small pan and hot water

c) Wood board 3/4 x 6 x 8"
Wood stick 3/4 x 3/4 x 14"
Wood 3/4 x 1-1/2 x 4-1/2"
Two 6" pieces of clothes-hanger wire
One 3 to 4" piece of clothes-hanger wire
One 2" piece of 1/4" dowel rod
Two pieces of tin-can metal 1/2 x 2"
One circular cardboard disk 6" diameter
One clothes pin
Four heavy 3" nails
Cement and glue
One gut string of a music instrument
One wool thread and wrapping cord, 10" each
One big cardboard box to fit over instrument and
a pan of hot water.

Cost: (exclusive of balance) 30¢

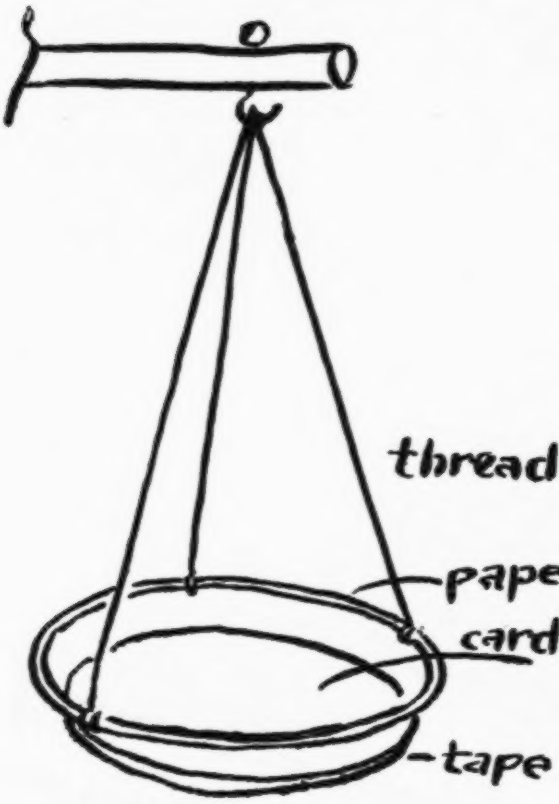

thread
paper cup rim
cardboard disk
tape

fig. 20

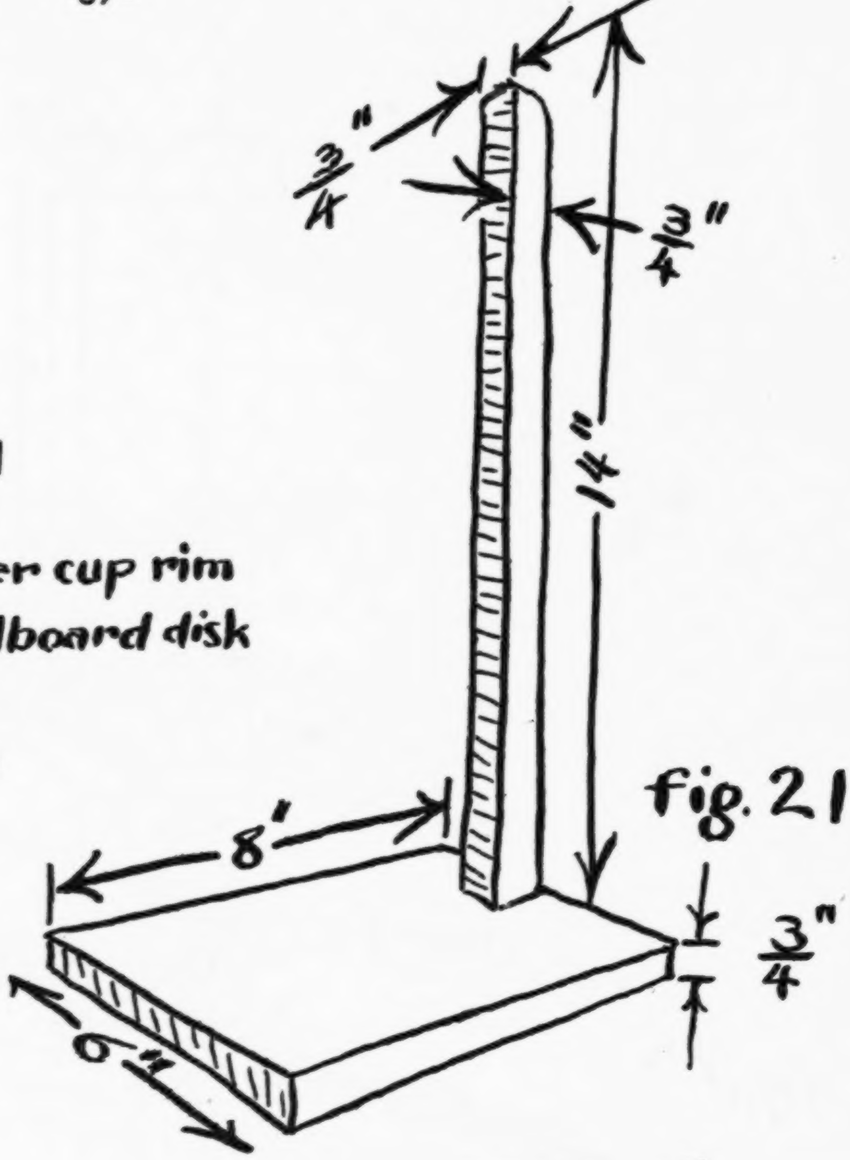

3/4"
3/4"
14"
8'
6"
3/4"

fig. 21

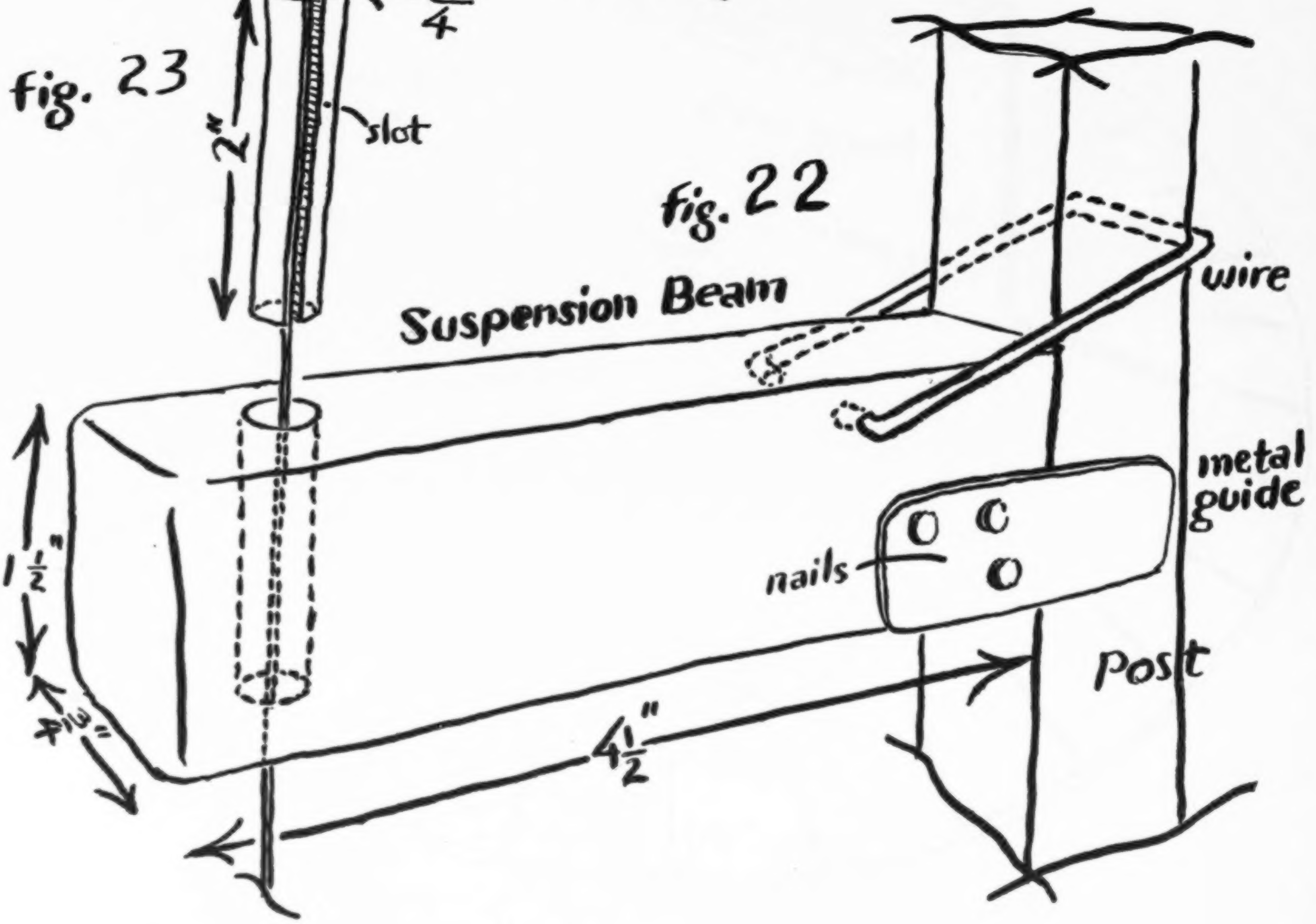

string
1/4"
2"
slot
Suspension Beam
wire
metal guide
nails
Post
1 1/2"
1/2"
4 1/2"

fig. 23

fig. 22

fig. 24

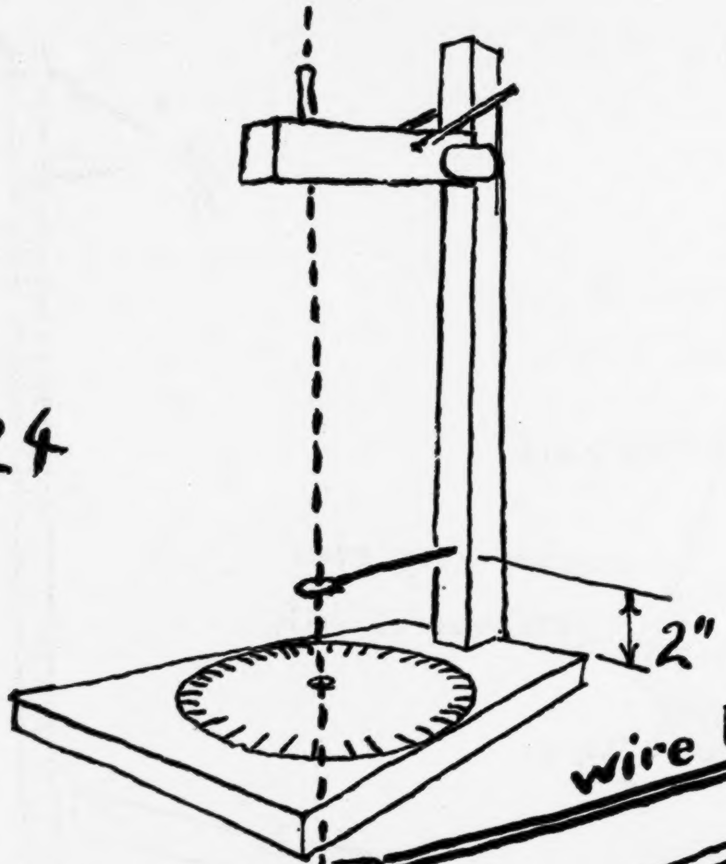
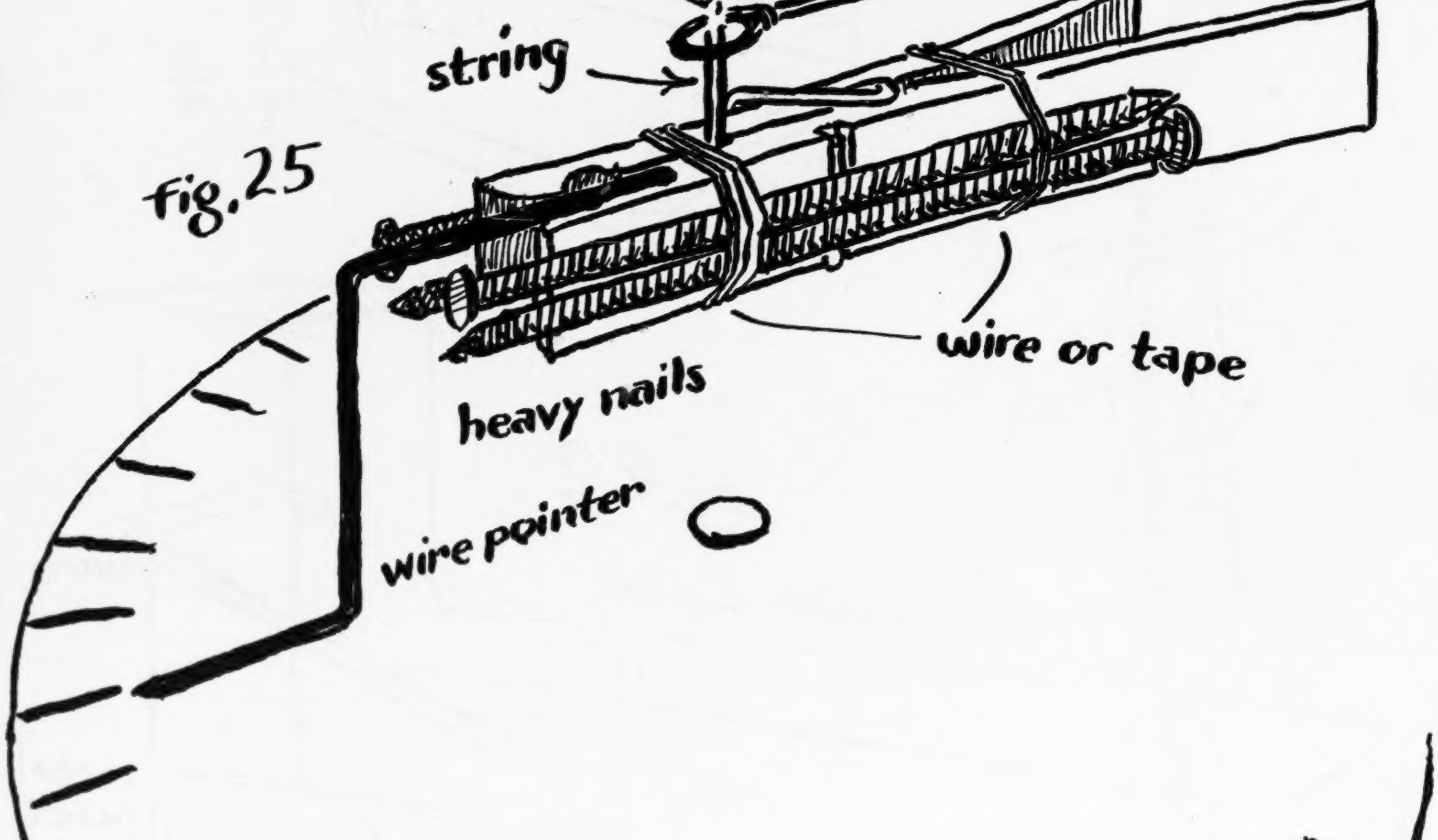

2"

fig. 25


wire loop
clothes pin
string
wire or tape
heavy nails
wire pointer
scale disk

9. Evaporation.

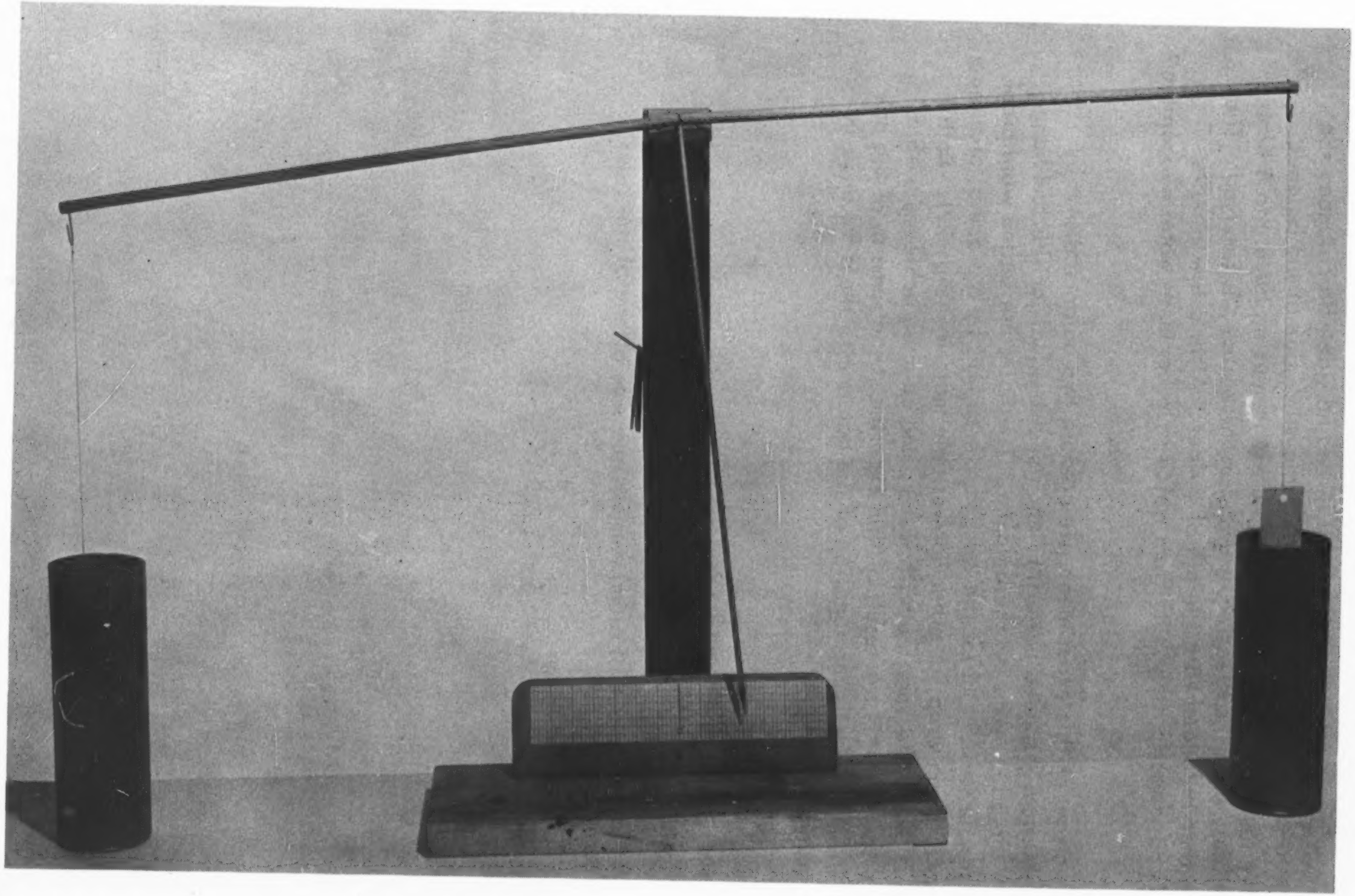


Plate 13.

a. Effect of Surface Area

To show the effect of surface area on the evaporation of water, we cut two equal strips, about 1 x 6", of blotting paper and punch small holes near the ends of each strip. We hang the one strip on one side of a balance, the other strip we fold in the middle and hang on the other side of the balance (Fig. 26). We then wet both strips by completely immersing them into a tumbler with water; excess water collecting as drops on the bottom, is removed. The two strips are then balanced with the aid of a rider. After a few minutes equilibrium is no longer present. 1) From which strip has more water evaporated? Why?

As a variant of this experiment, we prepare two balance dishes by punching three equally spaced holes into each of two equal jar lids and hanging them with thread or twine on the balance. The holes are sealed waterproof with melted candle wax. One of the lids is covered half by a piece of aluminum foil, wax paper, saran wrap, or other nonwettable material (Fig. 27). Both lids are then filled to the very top with water, and balance achieved with a rider, if necessary. 2. Is the result of this experiment the same as of the one above? 3. In which one is the reaction of the balance to the difference in evaporation quicker? Why?

Material:
- One balance
- Piece of blotter 2 x 6"
- Two small jar lids of equal size
- A few feet of twine or thread
- Small piece of aluminum foil the size of one of the lids
- Water
- Candle wax.

Cost: 5¢

b. Effect of Wind

As in the preceding experiment we hang two equal strips of blotting paper (both unfolded) on a balance, wet both by immersing into a tumbler with water, and equalize the weight by means of a rider. We then hold the one side of the balance beam and fan the one strip vigorously with a piece of cardboard, taking care, that the other strip is not ventilated. If an electric fan is available, we direct the air stream onto the one strip and away from the other. After a minute or so we note the imbalance. 4. Which strip evaporated more water, the ventilated one or the other? Why?

Material:
One balance
A piece of cardboard or electric fan
Water
Two strips of blotting paper, 1 x 6" each.

c. Effect of Water Temperature

Again we hang two equal strips of blotting paper (both unfolded) on a balance; we dip one into cold water, the other into hot water, and remove excess water from both. Adjust balance to equilibrium by means of the rider; this must be done very quickly, because the effect shows up immediately. For this reason it is sufficient to adjust for an approximate initial equilibrium. 5. Which water evaporated faster, warm or cold? Why?

As a variant of this experiment we can use the two dishes made in experiment 9, a, keeping both uncovered; we fill one with hot water, the other one with cold water. 6. Is the result the same as before? 7. Do you think that the temperature difference of the two water samples makes a difference in the results? Try this, by using very cold and very hot water.

Material:
One balance
Two strips of blotting paper, each 1 x 6"
Two jar lids of equal size
A few feet of twine or thread
Hot and cold water.

d. Effect of Radiation

As in the preceding experiments, hang two equal (unfolded) strips of blotting paper on a balance; immerse both into cold water and remove excess water. Then adjust balance with rider and place a 150 watt light bulb as radiation source 3 inches from one of the strips. 8. After a few minutes, which of the strips has evaporated more water? Why? 9. What is the similarity between this experiment and the previous one?

Note: If there is strong sunshine, we can use it as radiation source by exposing one of the strips to it, shading the other one.

Material:
- One balance
- Two strips of blotting paper, each 1 x 6"
- Cold water
- 150 watt light bulb as radiation source.

e. Effect of Relative Humidity

We find two equal mailing tubes of cardboard, 6" to 8" long and about 2" diameter. The cores of paper-towel rolls can be used for this purpose, or we can roll sheets of cardboard into tubes and wind twine around them to hold them together. Then we cut two equal strips of blotting paper, each half as long as the tubes and half as wide as the diameter of the tubes. The strips are wetted as in the preceding experiments and hung by means of short pieces of thread, from the balance so that they will be in the middle of the tubes without touching them. One of the tubes is thoroughly wetted with water, the other is left dry (see Plate 13). The balance is adjusted with a rider and after a few minutes the result is observed. 10. Does more water evaporate from the strips in a dry or a humid environment? 11. Why is this so? 12. In this experiment, is only the effect of humidity involved, or does another effect participate? If so, what other effect?

Material:
- One balance
- Two equal cardboard mailing tubes each 2" diameter, 6 to 8" long
- Two strips of blotting paper about 1 x 4"
- Water

Cost: 10¢

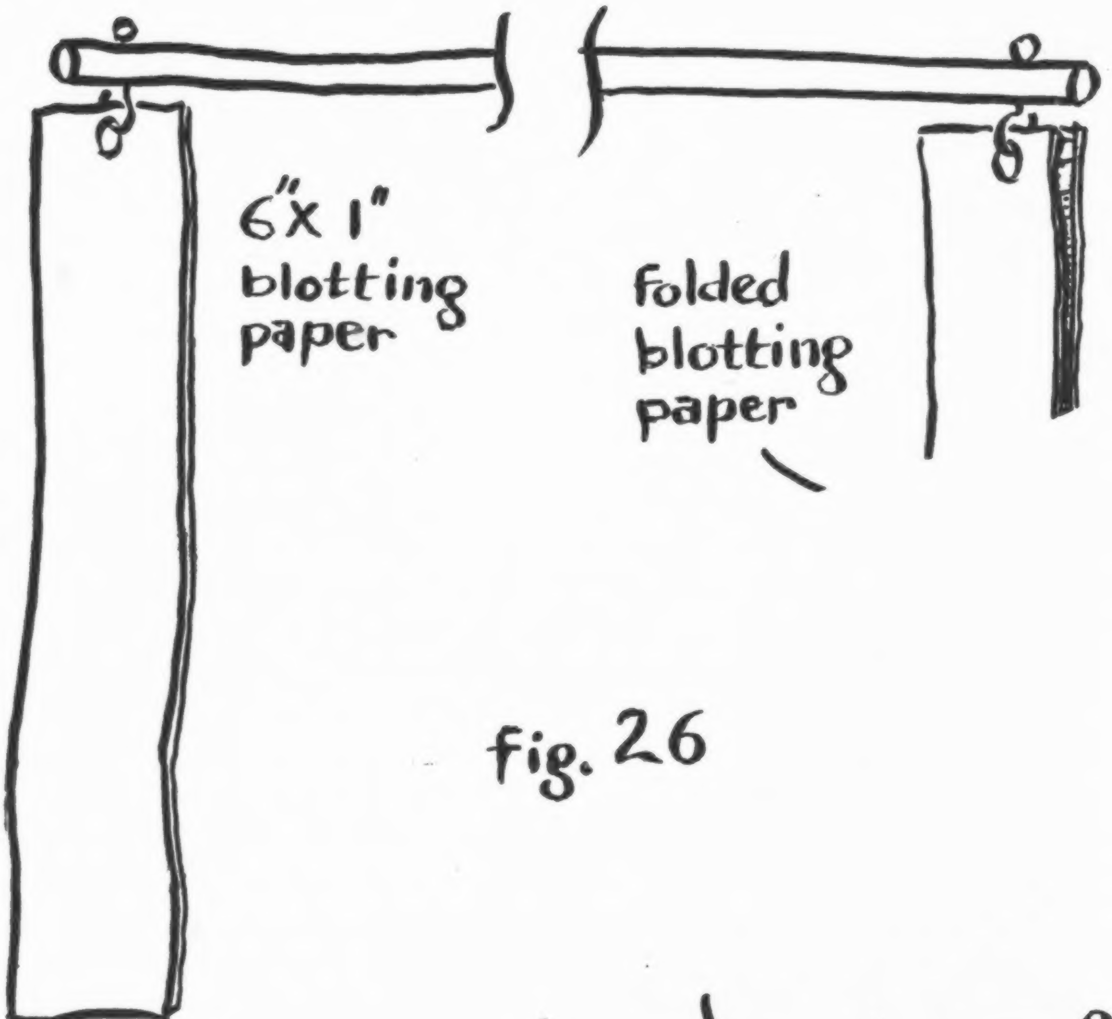

6"x 1"
blotting
paper
folded
blotting
paper

fig. 26

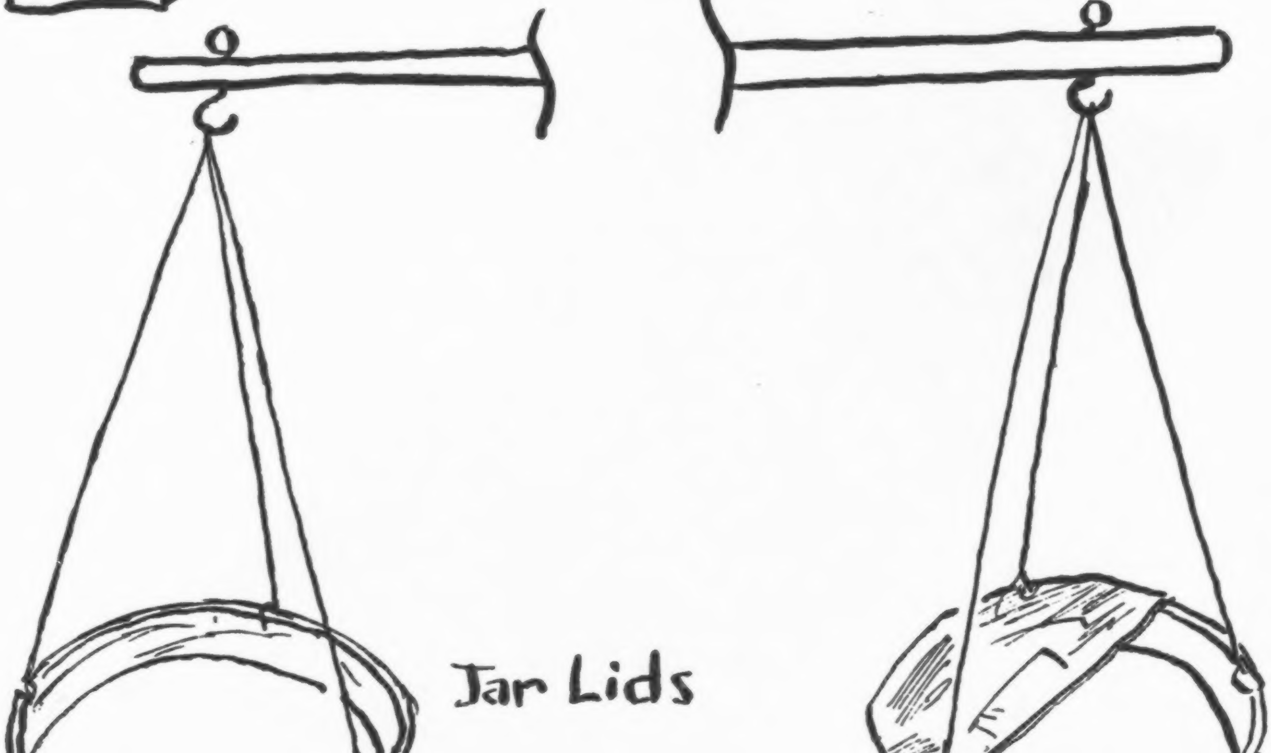
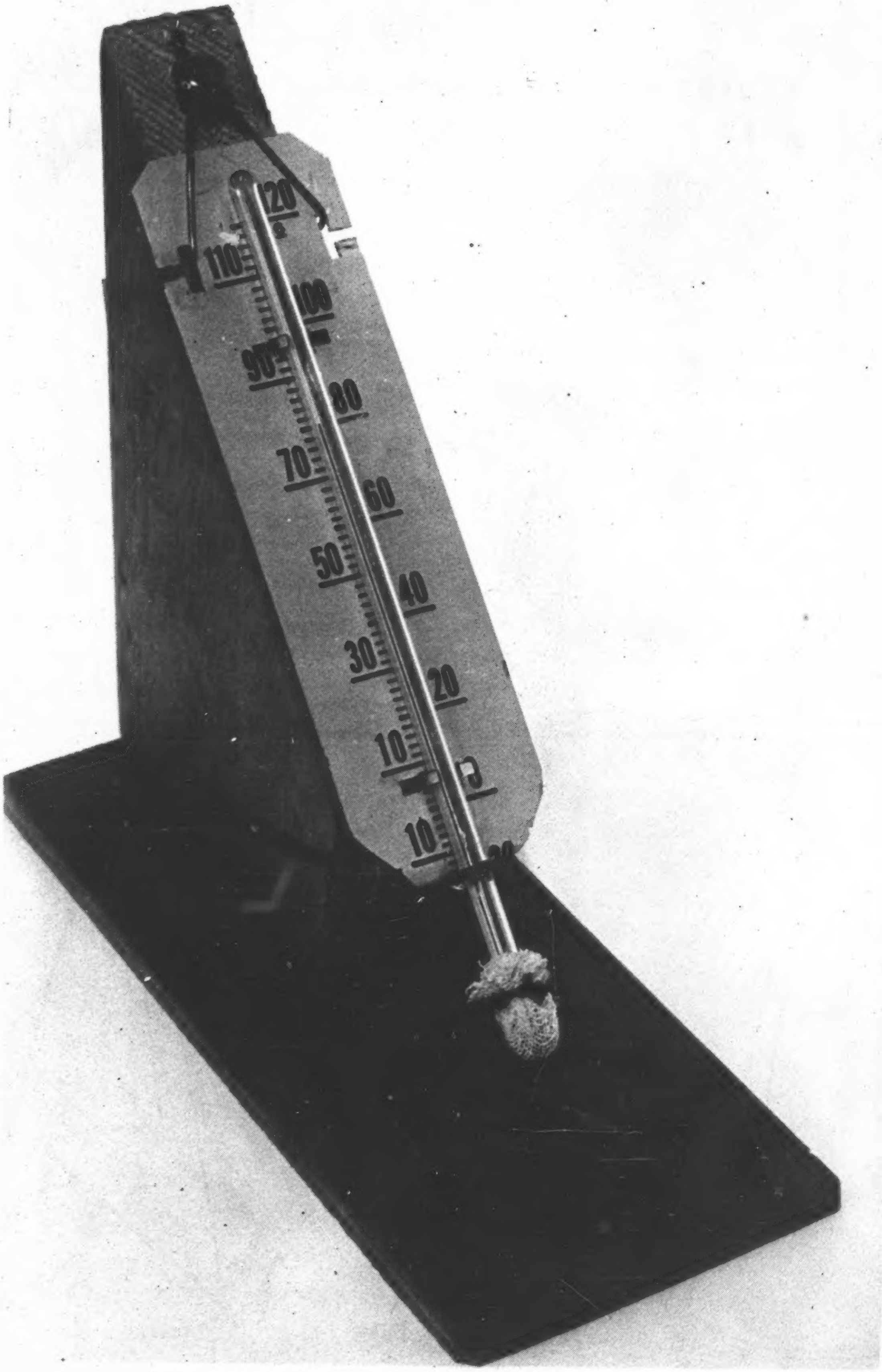

Jar Lids
aluminum foil

fig. 27

10. Wet-Bulb Effect.



120
110
100
90
80
70
60
50
40
30
20
10
10

Plate 14.

Heat is required for water to evaporate. This heat is removed from the water or from the wet surface, from which the water evaporates. When heat is removed from a substance, its temperature drops.

a) Take a small piece of thin cotton cloth and feel its sensible temperature. Then dip it into lukewarm water, hold it into the wind or air stream from a fan, or wave it back and forth a few times, and feel it again. 1. What is the difference between the sensible temperatures in the dry and the wet state? 2. Why is it possible that, during the cold season, laundry hung outdoors to dry may freeze although the air temperature is above 32°F?

b) Carefully cut away the lower portion of the backing of a thermometer to have the thermometer bulb and about 1/4" of the capillary free (Fig. 28). Use a fine saw blade and make sure that the thermometer mounting is otherwise not disturbed.

Fan the thermometer with a piece of cardboard (or electric fan) and take a reading of the air temperature after two minutes. Then tie a small piece of wet cotton cloth with thread around the thermometer bulb (Plate 14), fan it and read the thermometer again. 3. Do these thermometer readings support your previous conclusion based on your sense of touch?

Material:	One thermometer Small piece of cotton cloth Small piece of thread Piece of cardboard or electric fan Water

Cost: 40¢

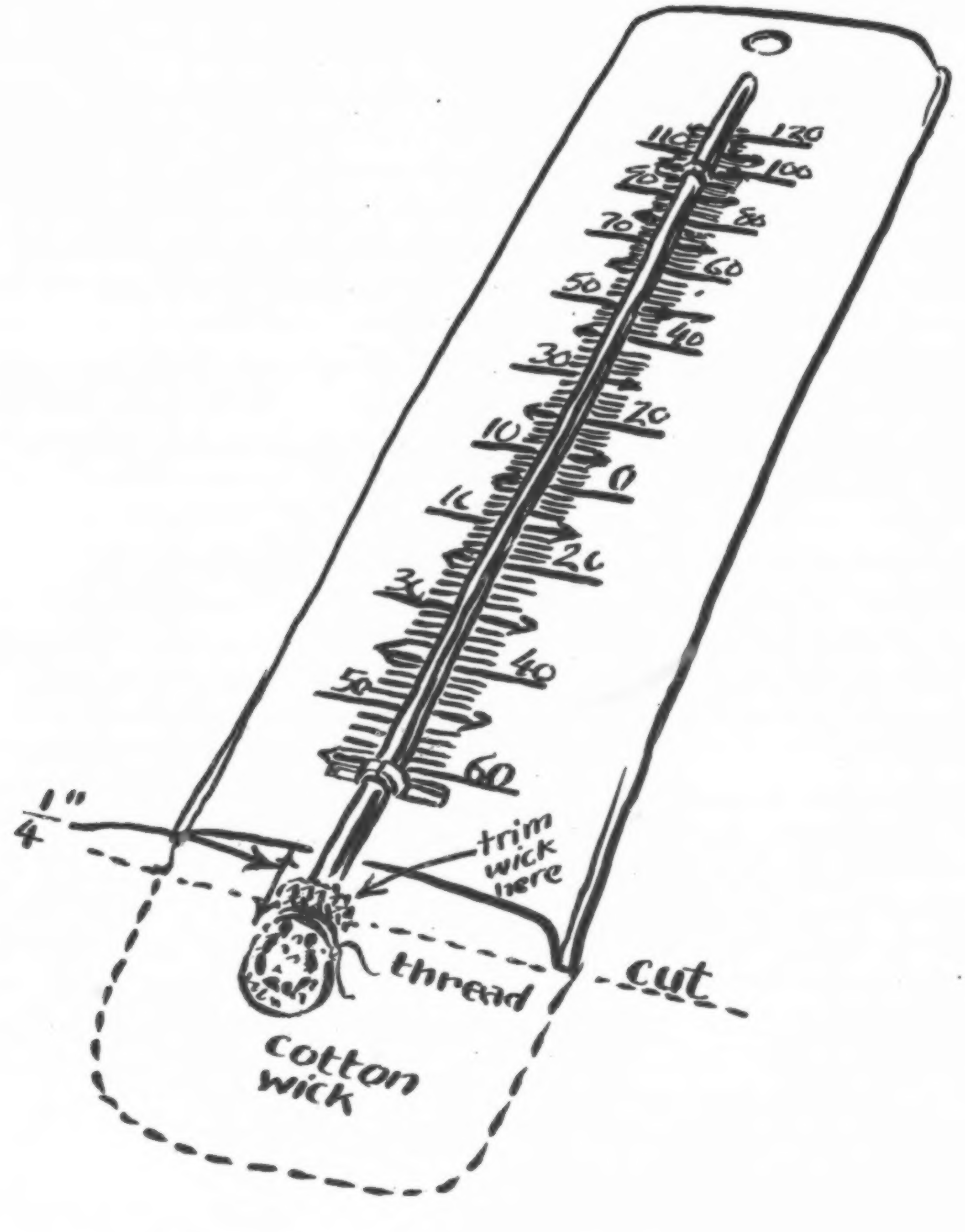

1"/4
trim wick here
thread
cut
cotton wick

fig. 28

11. Effect of Ventilation on Dry-and Wet-Bulb Thermometer Readings

When a thermometer is brought from a warm environment into a cold one, it takes some time for the thermometer to assume the temperature of the new environment. The warmer thermometer gives off heat to the cooler air surrounding it, thereby warming the air. If there is no air motion, a film of this warmed air adheres to the thermometer and insulates it from the cooler air farther away, so that the thermometer cannot indicate the proper air temperature. By ventilating the thermometer we can remove the insulating film of warmed air and hasten the equalization of the difference between the temperatures of the thermometer and that of the air we want to measure. In case the thermometer was initially colder than the new environment, similar considerations apply.

In a room, in which there is no draft, read a thermometer and then warm it with a candle, holding a sheet of aluminum foil between the flame and the thermometer bulb to protect it (Fig. 29). When the temperature reads between 110 and 115°F, remove the thermometer and start timing the temperature drop, when the temperature reads 110°F, recording the time accurately to a second for every 5° drop in temperature. (It is advisable to have a second person read and record the time on call from the one who reads the thermometer) 1. How does the rate of temperature drop change, as the reading approaches room temperature?

Then, as in Experiment 10, put a wet wick around the thermometer bulb (see Fig. 28.) Heat the wet bulb thermometer in the same way as above. Time the temperature drop as before. 2. What is the rate of temperature drop of the wet-bulb thermometer as compared to that of the dry-bulb thermometer? Why?

These experiments are now repeated, but after the warming, the thermometer is ventilated by fanning with a sheet of cardboard. If an electric fan is available, the effects of different wind speeds can be studied by placing the fan at different distances from the thermometer. 3. What is the effect of ventilation on the cooling rate of a dry-and a wet-bulb thermometer?

If ice is available or a refrigerator, the thermometer can first be cooled and the rate of warming measured. In case of the dry-bulb experiment, we can wrap the thermometer in aluminum foil, to prevent it from getting wet. We take a square of foil, the side length of which should be about twice the length of the thermometer; we place the thermometer bulb in the middle of the sheet and fold the corners up over the top of the thermometer (Fig. 30). We then can immerse it into a mixture of water and ice, until the thermometer reads less than 40°F; we start timing, when the temperature reads 40° and check the time for every 5° temperature rise.

Material: One thermometer
A small piece of cotton cloth and thread
A small candle
A sheet of aluminum foil 12" square
Some ice and water in tall tin can
A watch or clock with second hand

Cost: 50¢

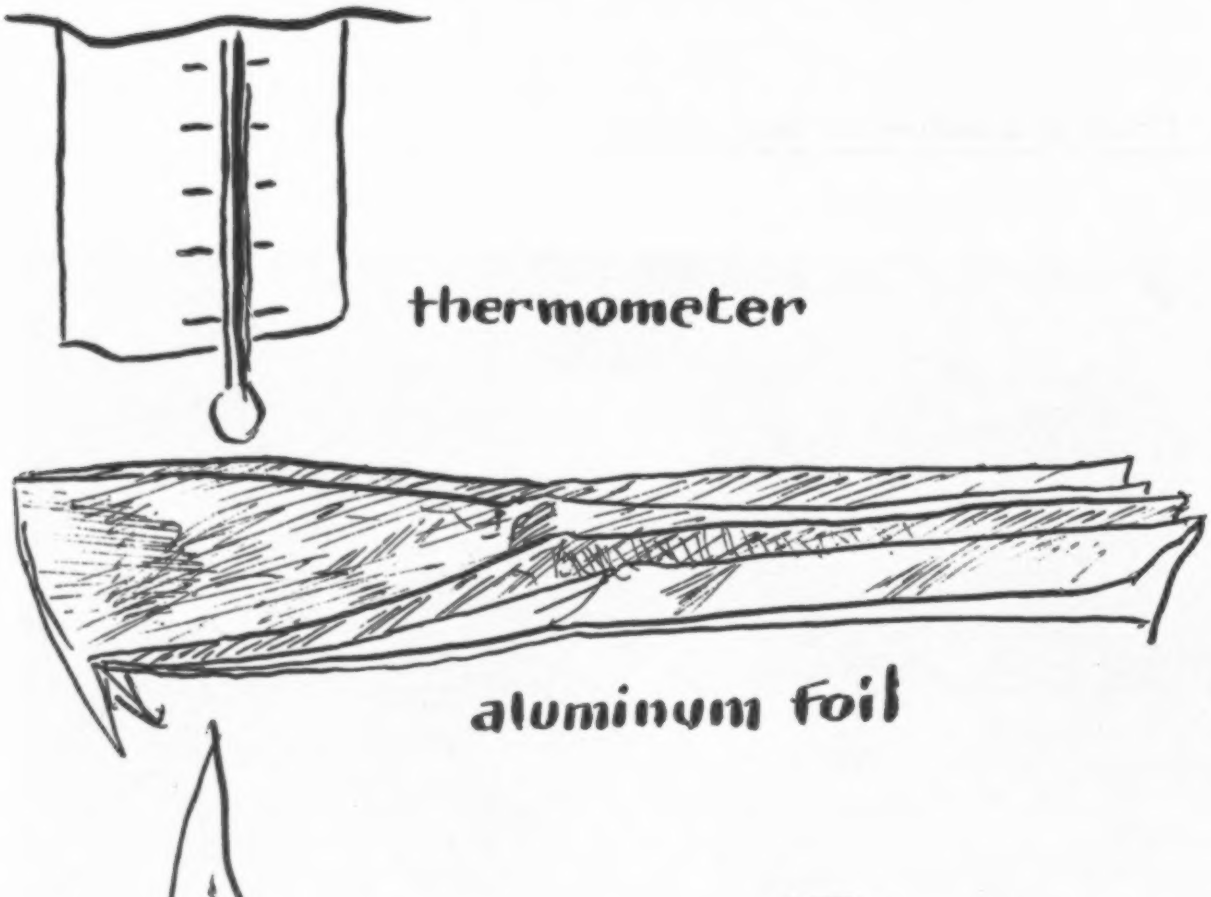

thermometer
aluminum foil
flame

Fig. 29

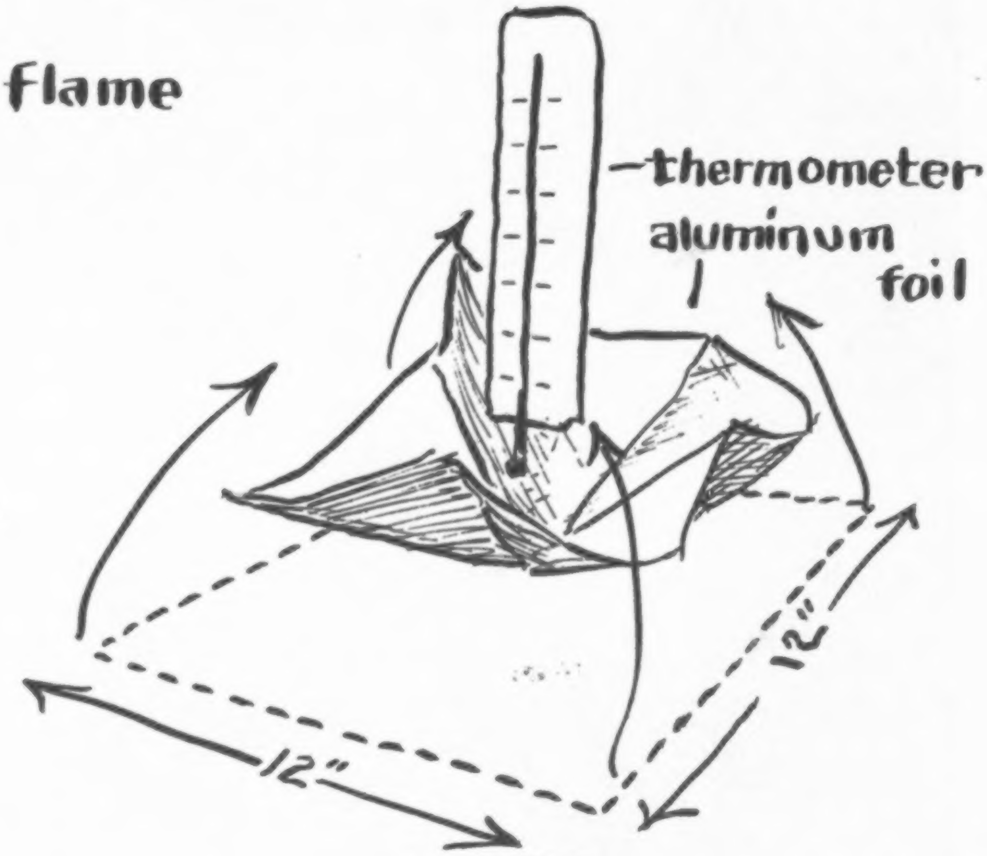

thermometer
aluminum foil
12"
12"

fig. 30

12. Effect of Radiation on Thermometers.

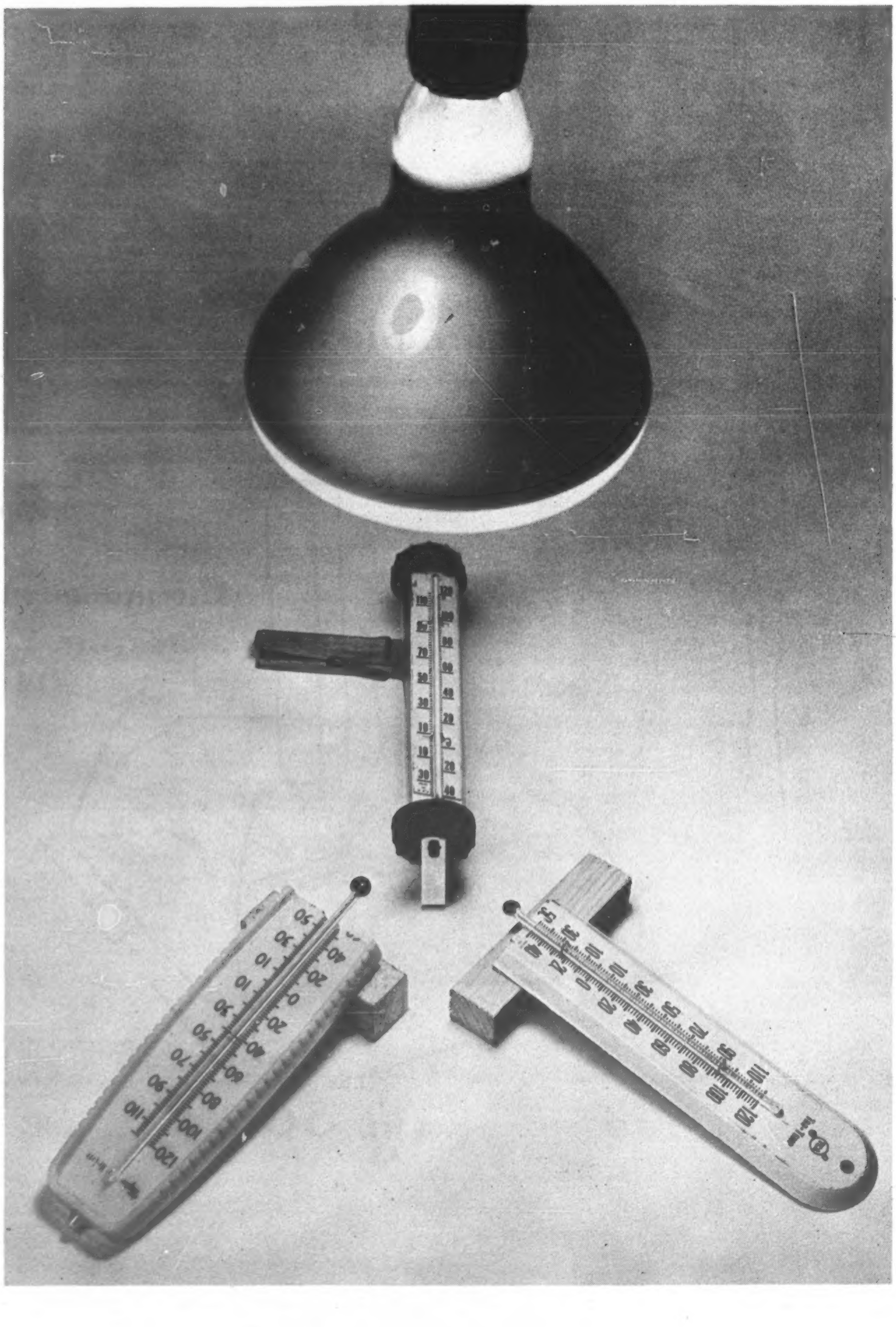


Plate 15.

The air temperature in sunshine is practically the same as that in the shade, because very little radiation is directly absorbed by the carbon dioxide and water vapor in the air and practically nothing by the other atmospheric gases. However, the thermometers with which we measure the air temperature must be carefully protected from radiation, because thermometers absorb a considerable amount of radiation. For this reason, a thermometer exposed to the air and to radiation will give a temperature reading that is higher than the air temperature by an amount that depends on the thermometer. How temperature readings taken under the influence of radiation vary with the thermometers themselves can be demonstrated as follows.

We take two, or preferably more thermometers of different types, such as a dial thermometer (bimetal), an ordinary thermometer mounted on metal or plastic or one of each, and a window thermometer in a glass or plastic tube. We first expose the thermometers in the shade, avoiding also radiation reflected from walls or the ground, and record the temperatures of each thermometer. The readings should be all the same, but, because of inaccuracies in calibration, there may be slight differences. Then we expose all thermometers fully and equally to sunshine for a few minutes and read again. If there is a wind, we must make sure that all thermometers receive the same amount of ventilation. In case no sunshine is available, a 150 to 200 watt light bulb can be used; we lay the thermometers on a table propped up in such a way that the thermometer bulbs are abount 2" from each other and the table surface. The light bulb is placed about a foot above the thermometer bulbs so that its distance from each is the same (Plate 15). We take readings before turning on the light and again 5 minutes after turning it on.

1. Are the temperature differences between the shaded and illuminated thermometers the same? 2. Would ventilation reduce these differences? Try it by repeating the experiment while applying equal ventilation to all thermometers by means of a piece of cardboard or an electric fan.

Material:	Two or more thermometers of different types. One 150 to 200 watt light bulb as radiation source. Piece of card board or electric fan.
Cost:	80¢ (for two Thermometers).

6

13. Effect of Radiation on Temperature of Land and Sea.

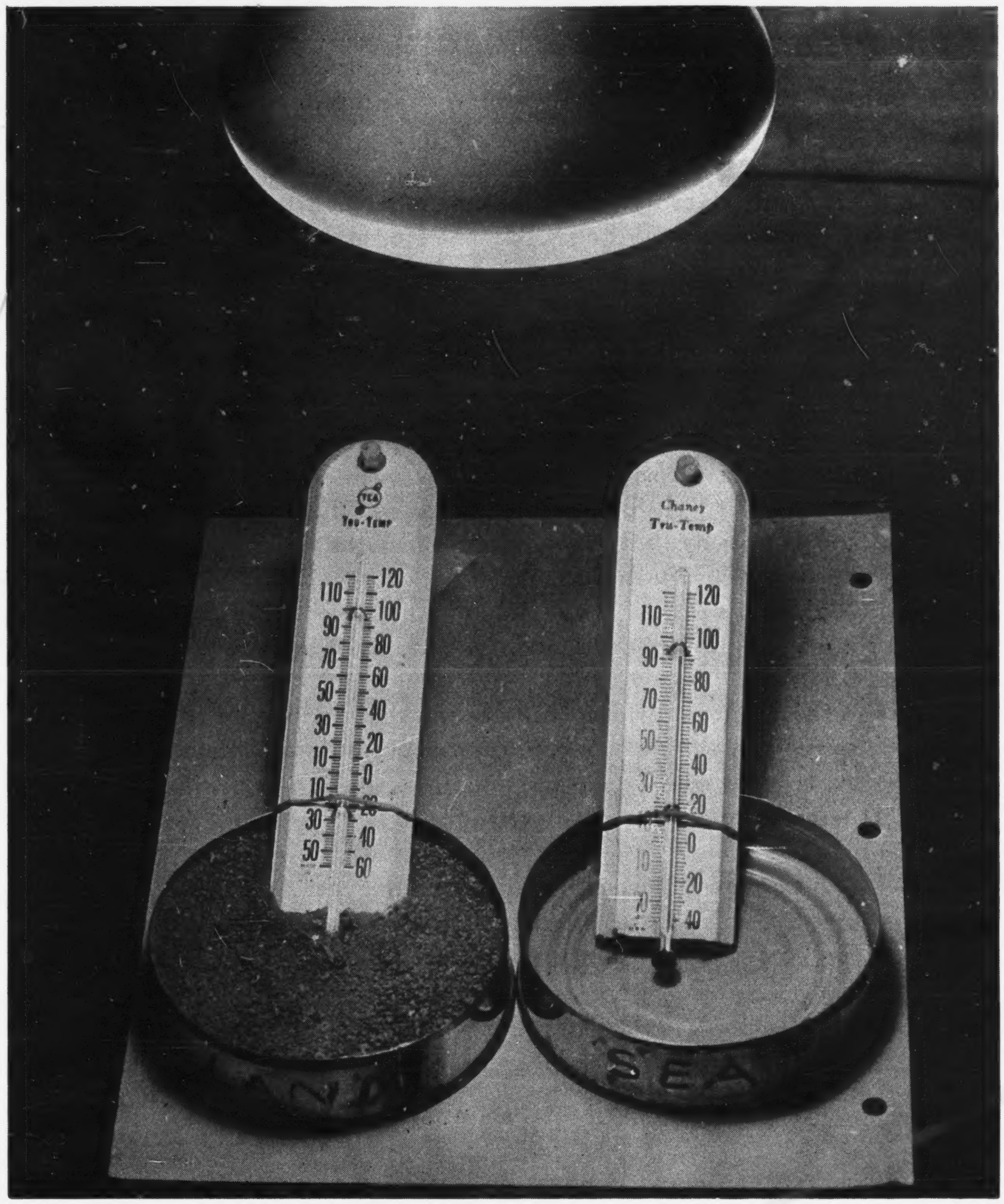

Tru-Temp
Chaney
Tru-Temp
LAND
SEA

Plate 16.

Many of the climatic features in various regions of the earth can be directly or indirectly attributed to the differences in thermal properties between land and sea. For example, the summer temperatures are higher, the winter temperatures are lower in the middle of a continent than they are at the same latitude near or over the ocean. The monsoon winds and the land and sea breezes are also a consequence of these differences. They can be summarized as follows: a) It takes about three times as much heat to raise, by one degree, the temperature of a unit volume of water than of a unit volume of soil; b) radiation is absorbed by a thin top layer of soil, whereas radiation penetrates the water to considerable depth; thus over a unit area a much smaller volume of soil is involved in absorbing radiation, than of water; c) water is mobile so that wind and water currents stir it up, whereas the soil is immobile; d) some of the radiation absorbed by the water is used to evaporate some of it, whereas all the radiation absorbed by dry soil is used to warm up the soil.

Very carefully cut the bottom portion of the holders of two identical thermometers with a fine saw blade, so that the bulbs and about 1/4" of the capillary tubings are free. Be extremely careful not to break the thermometers or to disturb the mounting of the capillaries to the scales. Cut off the top portion of two identical tin cans of 4" diameter of larger, so that only 1" remains (Fig. 31). (Other similar dishes can be used, but both should be the same.) Fill, to within 1/8" from the top of the cans, one with water, the other one with fine, sifted, dry soil. Let them stand for a while so that their temperatures will be approximately the same. Insert one thermometer bulb in the center of the can with water, so that the bulb is just covered with water. The other thermometer is inserted into the center of the can with soil, so that the bulb is just barely covered with soil. The thermometers should rest on the rim of the cans (a rubber band around the thermometers will prevent them from slipping) and be supported at the upper end: this is easily done by widening the holes at the top of the thermometer holders to about 1/4" and inserting a 1/4" dowel rod (or similar stick of wood) about 4" long. A rubber band can be used to prevent the dowel rod from slipping and yet make the inclination of the thermometers adjustable (Fig. 31).

a. Place a 150 to 200 watt bulb about 10" above the middle between the two cans so that both receive the same amount of radiation. Read the temperatures of the water and soil, then turn the light on and read temperatures every minute or so for about 10 minutes. Then turn light off and continue reading, until the temperatures are approximately what they were at the beginning. (Instead of a light bulb, sun light can be used, shading the cans before and after exposure with a piece of cardboard held not too near the cans.)

1. What did you observe? 2. What is the rate of temperature change in water as compared to that in soil during exposure to radiation? After exposure?

b. Now push the thermometers into the soil and water so that the bulbs rest on the bottom in the middle of the cans, and repeat the experiment. 3. What can you say regarding the penetration of radiation?

c. Place the thermometers bulbs into their original position just barely under the surfaces of the soil and water. Sprinkle water on the soil without soaking it and repeat the experiment. 4. What are the temperature changes of wet soil as compared to dry soil? How do you explain this difference?

Material: Two tin cans, 4" diameter
Two identical thermometers
Two 1/4" dowel rods, each 4" long
Four rubber bands
One 150 to 200 watt light bulb
Water and fine, sifted soil.

Cost: 80¢ (for two thermometers).

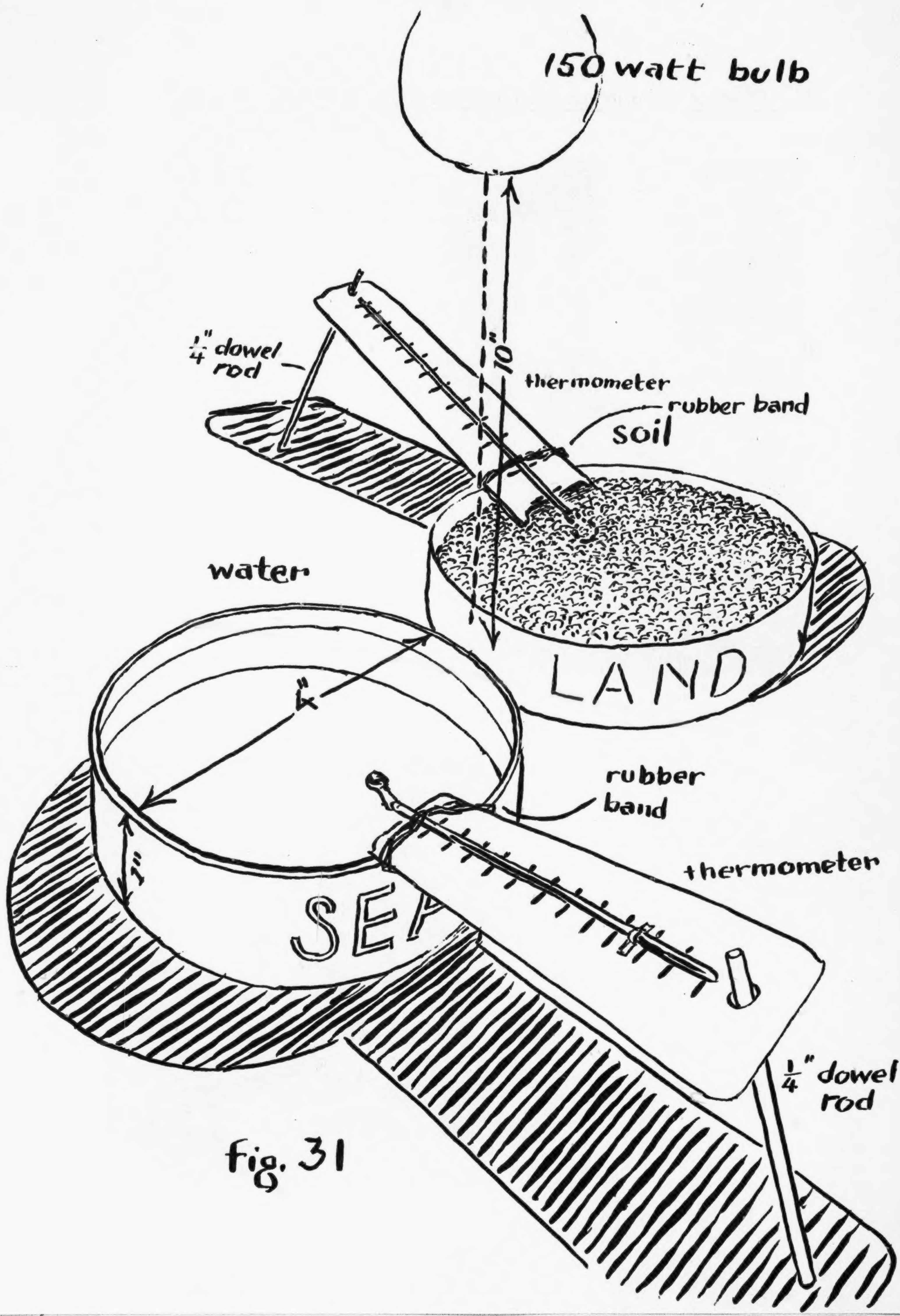

150 watt bulb
10"
$\frac{1}{4}$" dowel rod
thermometer
rubber band
soil
water
LAND
6"
1"
rubber band
thermometer
SEA
$\frac{1}{4}$" dowel rod

fig. 31

14. Effect of Radiation on Air Temperature over Different Surfaces.

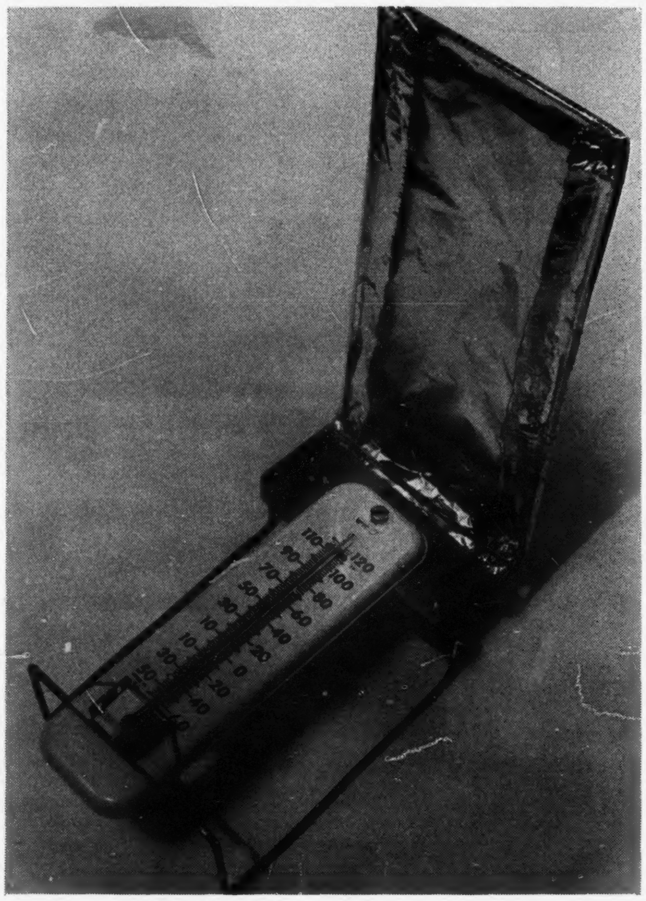
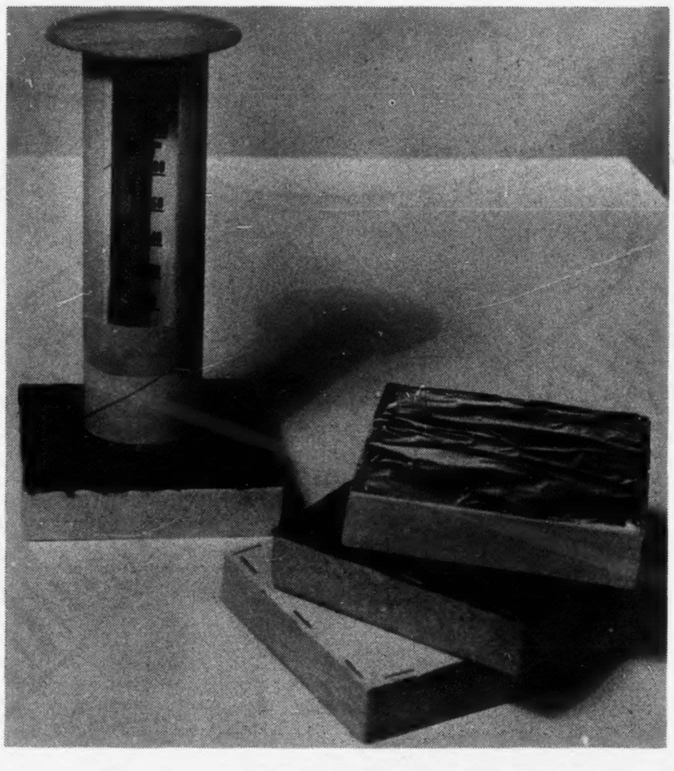


Plate 17.

Plate 18.



In Experiment 13 it was shown how, under the same radiation, soil and water surfaces acquire different temperatures. Here, the differences in the temperature of the air immediately above various surfaces will be shown.

a) On a sunny day, we measure the air temperature 2" above the ground; we select a lawn (preferably with short, dense grass), bare ground, a concrete or black-top road surface, and a water surface, if available, for our measurements. Two precautions must be observed: 1. the thermometer must be shielded against direct radiation from the sun; 2. there should be only a very slight wind or calm, and the spot of measurement should be so located, that the wind passes over the same type of surface for at least 100 ft. before reaching the thermometer.

To facilitate the temperature measurements we can construct a simple stand for the thermometer with a piece of wood 3/4 x 1-1/2 x 4", two pieces of 24" of stiff wire (clothes hanger), and a sheet of aluminum foil 5 x 10". From Fig. 32 and Plate 17 the construction is evident; two holes are punched into each of the small sides of the wood into which the ends of the stand-wire and of the shade-frame wire are inserted. The thermometer is fastened with a screw to the middle of the block of wood and with a rubber band to the wire stand. The aluminum foil is crimped around the shade frame with the glossy side outward. The thermometer is set on the chosen surface so that the entire length of the thermometer is shaded from sunlight. Readings are taken after three to five minutes . The thermometer should be watched continuously, so that it can be removed immediately, should the temperature reach the top of the scale. For measuring the temperature over a water surface, the apparatus is set on a wooden float. 1. Over which surface is the air temperature highest? Lowest?

b) For a laboratory experiment we take three blocks of wood 3/4 x 3 x 3" and glue or staple to their top and bottom surfaces 3 x 3" squares of a) aluminum foil, b) white glossy paper, c) black velvet, d) rough grey cardboard, e) glossy or rough green paper, f) coarse sand paper, or similar materials. We hang a thermometer, from which the bottom of the backing has been carefully removed to have the bulb stick out, with string or wire from a cardboard disk and place it in a mailing tube that is just wide enough for the thermometer to hang freely inside. We cut off the bottom of the tube so that the thermometer bulb is 1/4" above the bottom rim. We then cut a slot into the tube from the top, wide enough and long enough to see the thermometer scale. The slot is covered with a strip of transparent plastic (seran wrap will do) and this is taped or glued to the tube. (See Fig. 33).

We then place a 150 watt light bulb at a distance of 1" over the middle of one of the prepared wood blocks (Fig. 34). After 5 minutes exposure to the light we remove the block and place the tube with thermometer in the center of the block (see Plate 18) and, having read the temperature beforehand, read the subsequent temperatures every 1/2 minute for three minutes, and record them.

This procedure is repeated for all the different surfaces. The thermometer should be allowed to return to room temperature before each measurement; this can be speeded up by ventilating the thermometer (see Experiment 11). Determine the highest rise in temperature obtained with each of the surfaces; make a list of the surfaces in order of increasing temperature rise. 2. Is the air warmer over dark or over light surfaces? 3. Is the air warmer over rough or glossy surfaces?

Material: a)
One thermometer
Two pieces of stiff wire (clothes hanger) each 24" long
One wood block 3/4 x 1-1/2 x 4"
One sheet of aluminum foil 5 x 10"
Two rubber bands
One screw

Cost: 45¢ (including thermometer)

b)
One thermometer
Three blocks of wood 3/4 x 3 x 3"
One mailing tube about 6 to 10" long, 2" diameter
Strip of transparent plastic 1-1/2 x 4"
Cardboard disk, 3" diameter
One 3" square each of white paper, aluminum foil, black velvet, rough grey cardboard, green paper, sand paper, etc.
Glue, tape, staples, string
One 150 watt light bulb as heat source

Cost: 50¢ (including thermometer).

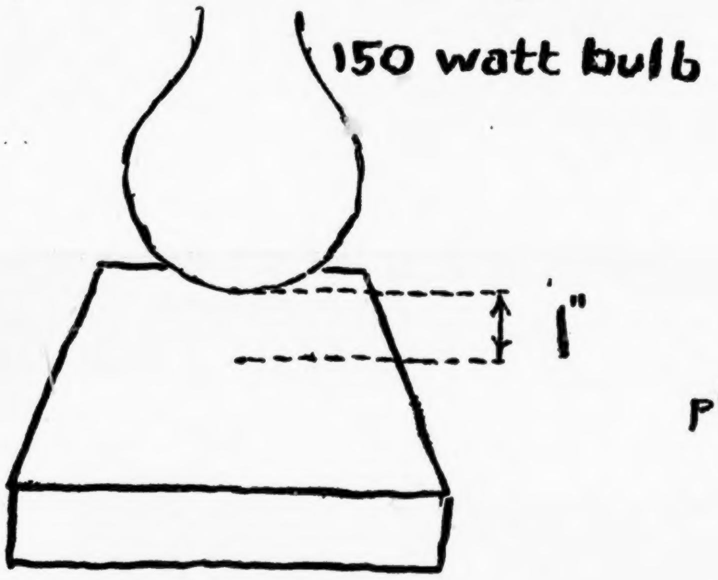

150 watt bulb
1"

fig. 34

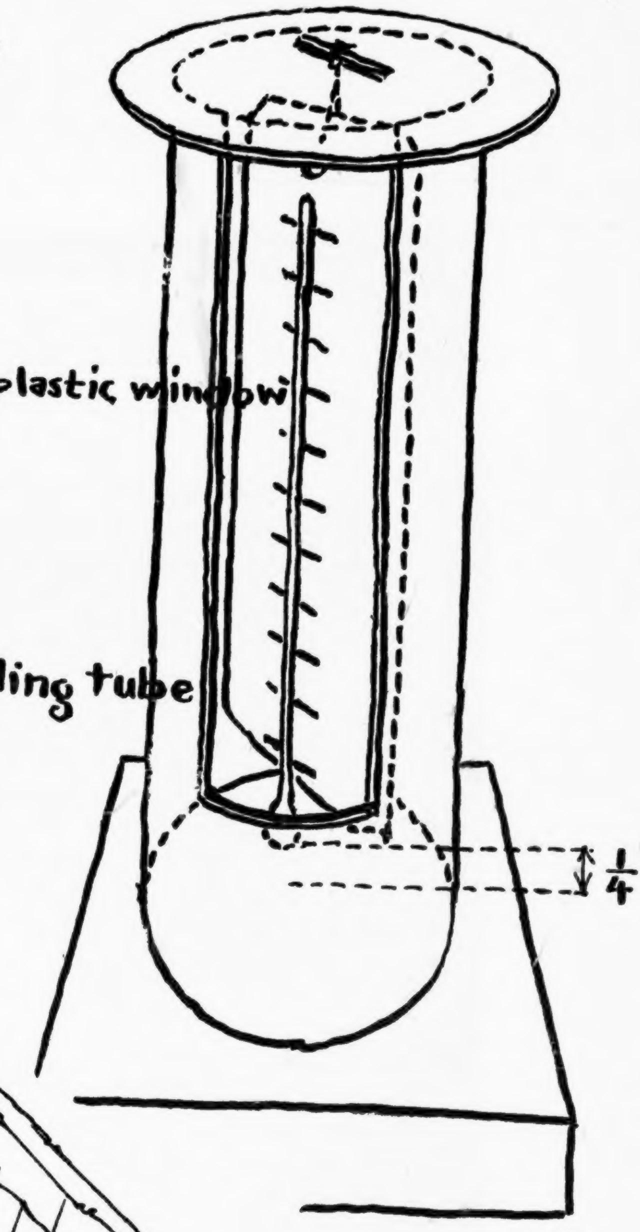

plastic window
mailing tube
$\frac{1}{4}$"

fig. 33

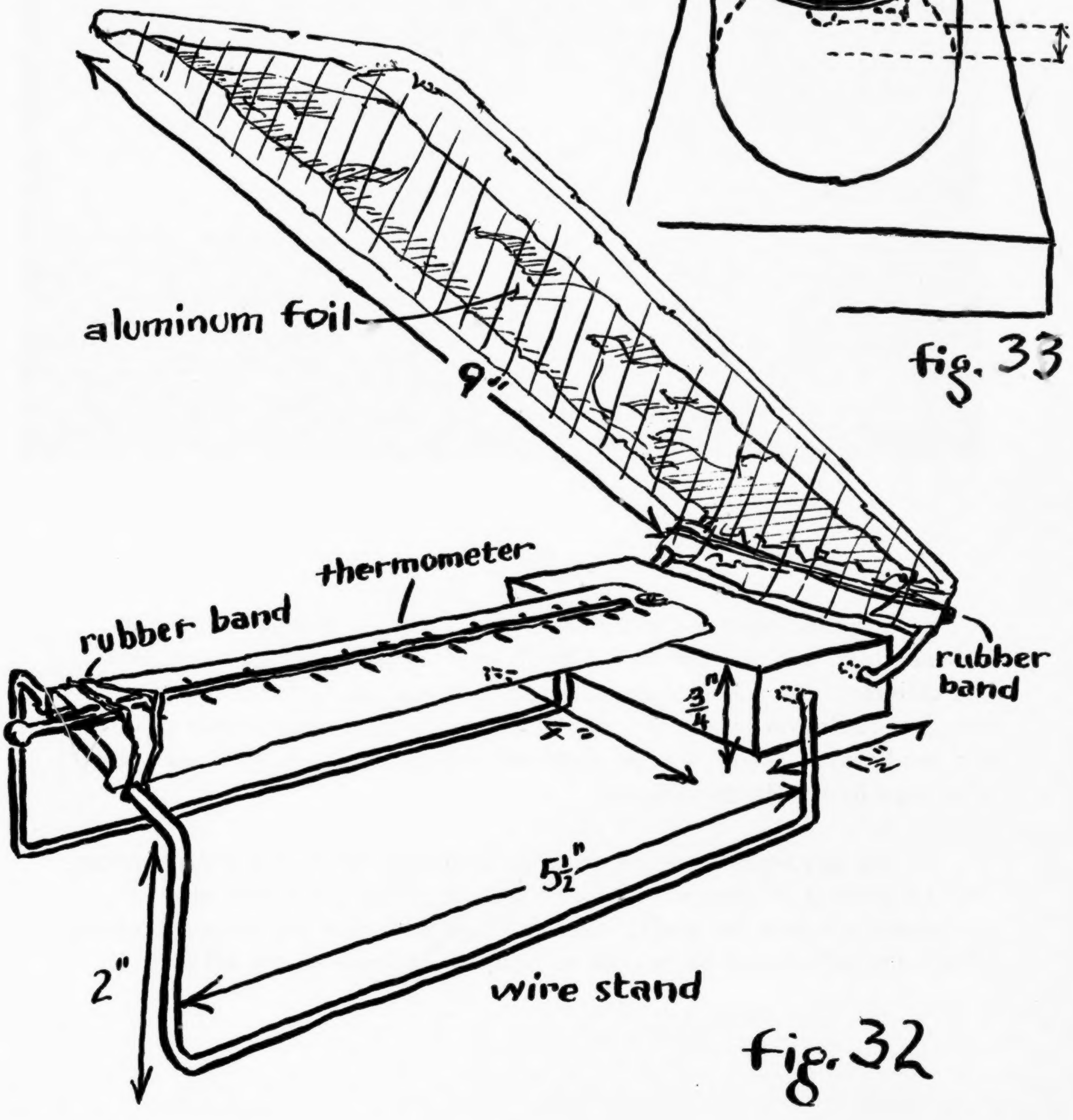

aluminum foil
9"
thermometer
rubber band
rubber band
$\frac{3}{4}$"
$1\frac{1}{2}$"
$5\frac{1}{2}$"
2"
wire stand

fig. 32

15. Sea Breeze.

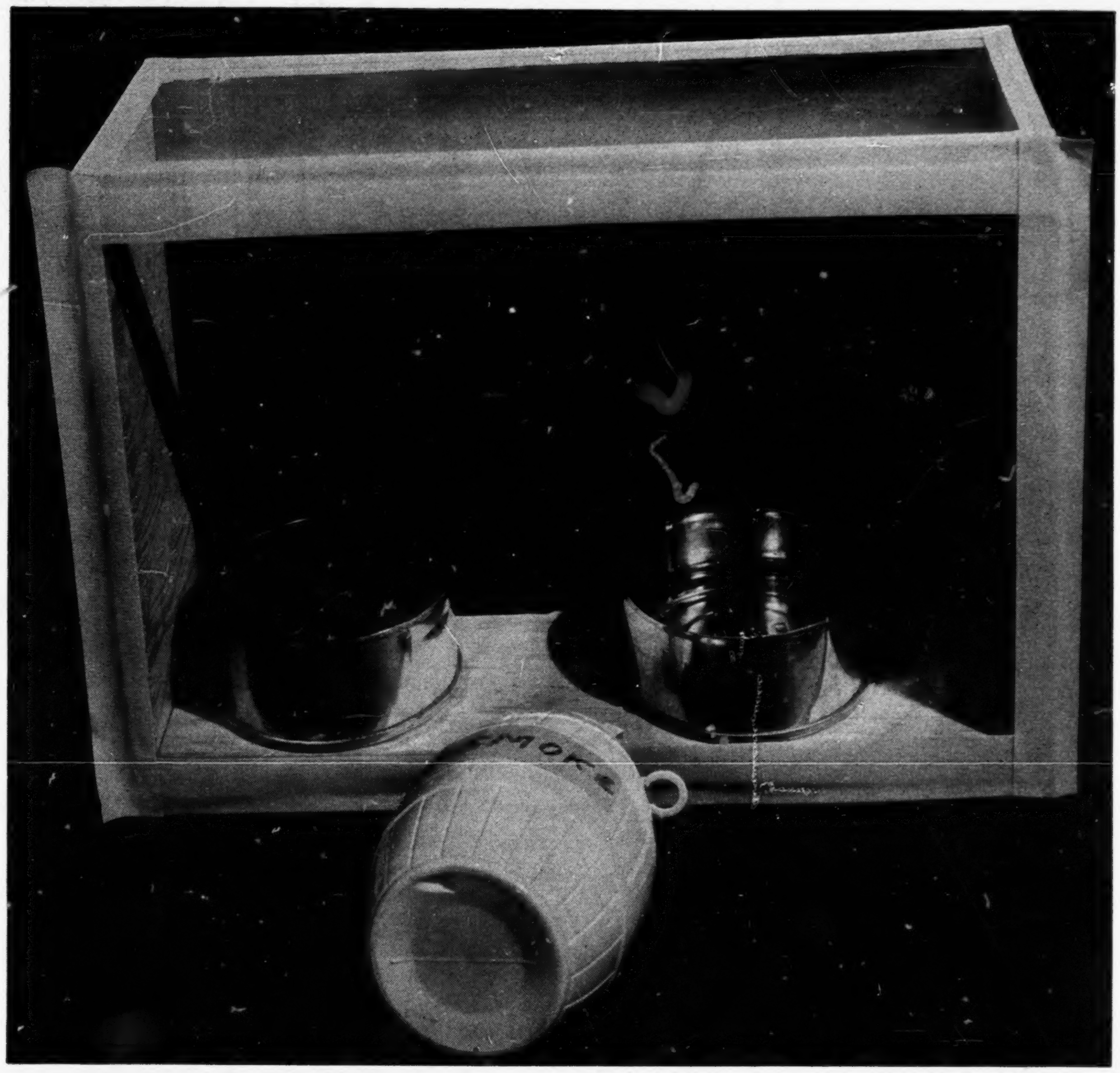


Plate 19.

In Experiments 13 and 14 the differences in thermal properties between land and sea and their effects on the air temperature are shown. The difference in temperature between land and sea surfaces produced by the same radiation intensity leads to a circulation system known as land- and sea breeze, which can be observed to blow across shore lines under otherwise favorable conditions.

The sea breeze can be demonstrated with the following apparatus: Two tin cans of 3" diameter are cut down to 1" height (other shallow containers can also be used). One is filled with fine dry soil, preferably sifted; the soil should be as dark as possible to increase the effect. If only light soil is available, it can be darkened by mixing soot or charcoal powder into it. The other can is filled with water. Both are placed into a box made of wood, metal, or cardboard, with transparent top and transparent front. A wooden box can be made of a piece of wood board, 3/4 x 3 x 10" as bottom, a sheet of plywood 1/4 x 8 x 10" as back, and two sheets of plywood 1/4 x 3-1/4 x 8" as sides. These are nailed and/or glued to the base; the free corners of the sides (top front) are braced with a stick of wood 1/4 x 3/4 x 10" as shown in Figure 35. For better visibility of the smoke used in the experiment, the inside of the back and side panels should be painted flat-black. Then we fasten, with cement or tape, a sheet of glass or plastic to the top; a transparent plastic sheet is taped to the front, so that it can be removed for setting the two tin pans inside or taking them out. At the middle of the bottom edge of the front panel we cut a small hole just above the base (Fig. 35) through which we can insert a short piece of rubber hose or the nozzle of a smoke pump (see Section III,D). The hole is covered with a piece of tape.

Now set the pans into the box at either end of the base and tape the front panel on the box. Make sure that all the edges of the box are tightly sealed. Then place a 150 or 200 watt light bulb about 4" above the middle of the top, so that the same radiation is received by each of the pans. The bulb is turned on, and after 15 to 20 minutes we blow very slowly some smoke through the hole in the front panel, being careful not to create any eddies. The smoke should merely seep into the box. Watch the smoke drift and describe the motion. 1. Over which pan is the air movement more vigorous, in what direction, and why? 2. Which portion of the air motion represents the sea breeze?

Material:

Two tin cans of 3" diameter
One piece of wood 3/4 x 3 x 10"
One piece of 1/4" plywood 8 x 10"
Two pieces of 1/4" plywood 3-1/4 x 8"
One stick of wood 1/4 x 3/4 x 10"
Some flat-black paint
One sheet of transparent plastic (or glass) 3-1/4 x 10-1/2"
One sheet of transparent plastic 8 x 10-1/2"
Some dark, sifted soil; water
Glue, tape, nails
A smoke source (cigarette)
A 150 or 200 watt light bulb.

Cost: 35¢

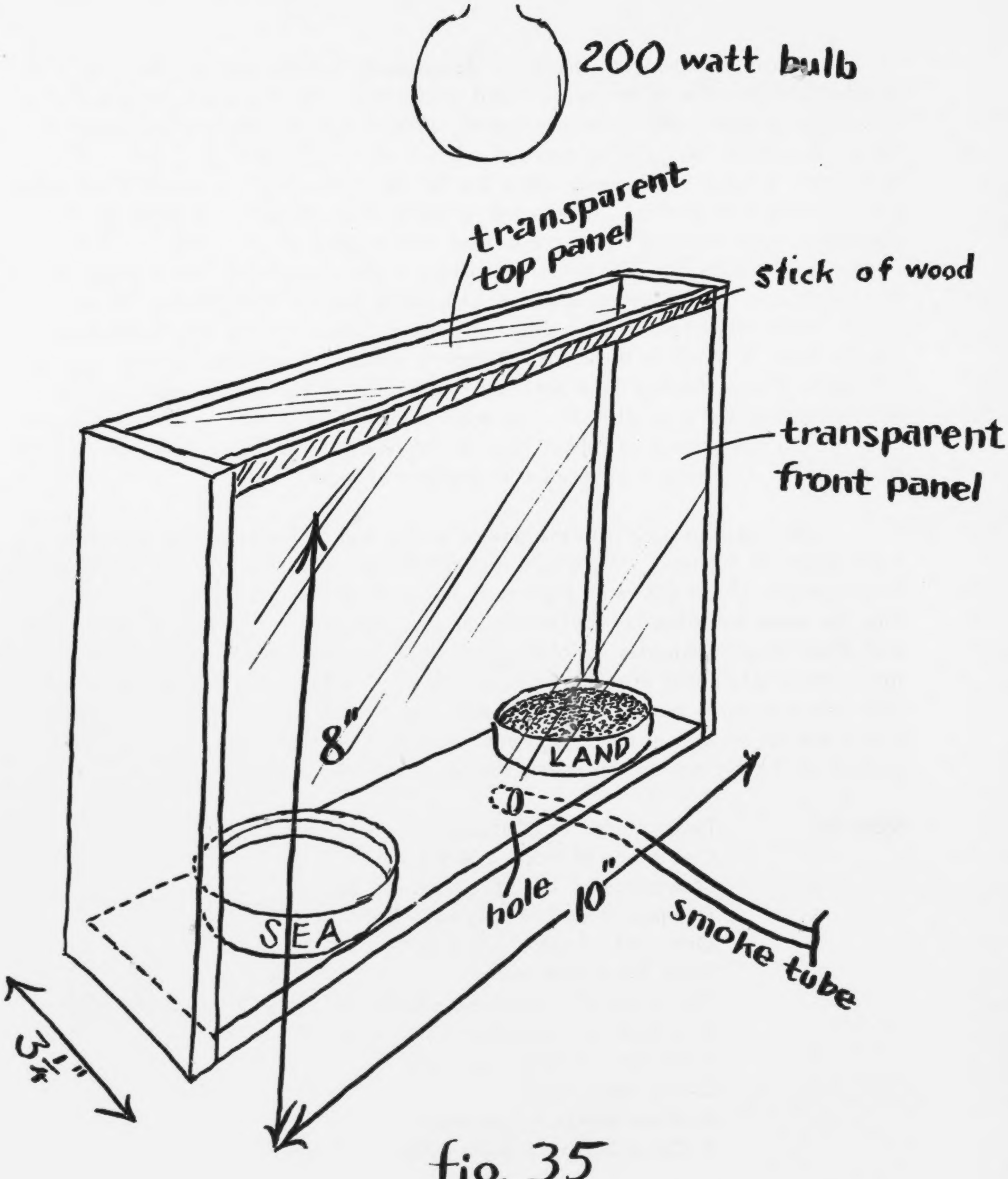

200 watt bulb
transparent top panel
stick of wood
transparent front panel
8"
LAND
SEA
hole
10"
smoke tube
3¼"

fig. 35

16. Convection Cell.

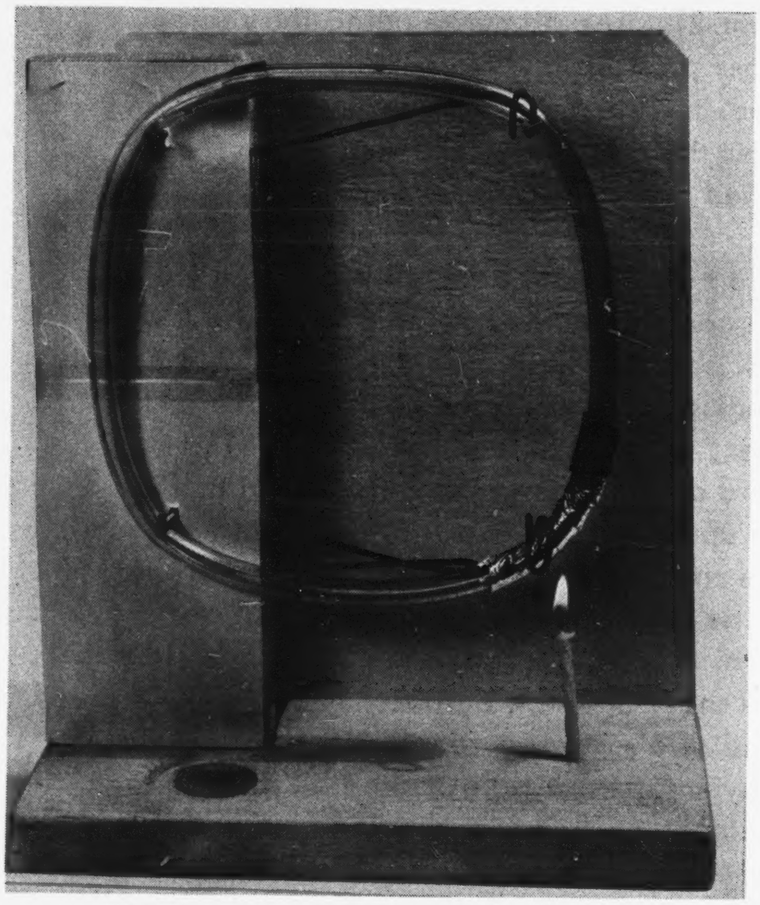


Plate 20.

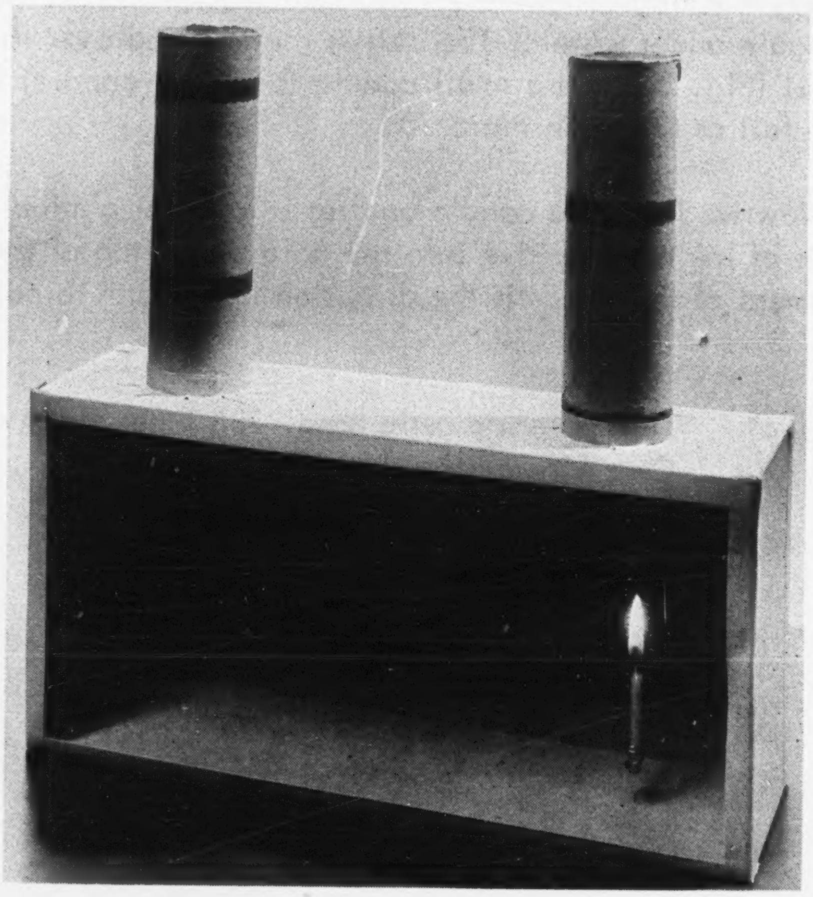


Plate 21.

Differences in heating of various portions of the earth's surface (Experiments 13 and 14) cause corresponding differences in the temperature of the air above these portions. Where the air is warmed, it expands and therefore its pressure drops (Experiment 2). The air surrounding the region of warming has then a relatively higher pressure and moves into the region of lower pressure, pushing the warmer, less dense air upward. Compensating downward movement of air occurs over the relatively cold region, so that a complete circulation is soon established.

a) We can demonstrate such a circulation cell with water as a fluid, instead of air. The construction of a convenient size is described here. A piece of wood board, 3/4 x 3 x 8" is used as a base; another piece, 3/4 x 3x10" is fastened upright to the base with nails or glue and serves as support for the cell (Fig. 36). A wire clothes hanger, minus hook and neck, is cut in two halves, shaped into hooks (one upward and one downwards) as shown in Fig. 36. They are fastened with staples to the upright support so that the lower, downward directed hook is about 3" above the base. At the same level with the hooks, two nails are hammered into the support so that they stick out about 1/2". The upright support is then painted white or covered with a piece of white paper. Against the back edge of the base, a sheet of white cardboard, 8 x 10", is glued or tacked. Then we flare out one end of a piece of transparent plastic hose, about 23" long and 3/8" diameter, by inserting a pair of pointed pliers and spreading, until the other hose end can be pushed into the widened end to make a ring. A small hole about 1/8"diameter is cut into the top of the hose ring and a strip of aluminum foil 1 x 10" is wound around the lower right corner. We immerse the ring completely into water, open it to let all the air out, and close it again under water. The cell is then placed over the nails and hooks of the support (Fig. 37) and a small candle (birthday-candle) is placed under the aluminum foil as shown in Plate 20.

Now we light the candle and let it burn for a minute or two, then put a drop of ink or other dye into the hole at the top of the cell. Observe the movement of the dye. Is the direction from warm to cold or from cold to warm?

Material:	a)	Transparent plastic hose, 23" long, 3/8" diameter. One wire clothes hanger One piece of wood 3/4 x 3 x 10" One piece of wood 3/4 x 3 x 8" One small candle One strip of aluminum foil 1 x 10" One piece of white paper 3 x 9" One piece of white cardboard 8 x 10" Nails, staples, glue, water, ink.
Cost:		50¢

Note: If no transparent plastic hose is available, the cell can be made from 4 eye droppers and four pieces of ordinary rubber hose, as shown in Fig. 38.

b) An alternate convection cell, in which the circulation is not closed, can be made as follows. We need two sheets of moderately stiff cardboard, each 8-1/2 x 11" (backs of notepaper pads); one we bend to form the bottom (3 x 11") and the back (5-1/2 x 11"); out of the other we cut three pieces, two of them 3 x 5-1/2", one 3 x 11". We then tape these into a box 11" long, 5-1/2" high, and 3" deep; two holes are cut out of the top, the centers of which should be about 2" from the ends and the diameters a little smaller than the inner diameter of the core of a paper towel roll (or two toilet paper rolls). This tube is cut in half (about 5" length each) and the two pieces taped over the holes, as shown in Fig. 39. The front of the box is then closed by taping a sheet of glass, or transparent plastic (seran wrap can be used), over it. Make sure that all edges of the box are tightly sealed. We wind the end of a stiff piece of 12" wire around a small birthday candle, make a hook at the other end, and hang it over the rim of one of the chimneys (see Fig. 39 and Plate 21). Be careful to hang the candle so that the box does not catch fire. Light the candle and hold a smoking cigarette or smoldering piece of string over the other chimney. Watch the travel of the smoke and draw a picture of the circulation.

Material: b)
- 2 sheets of cardboard, each 8-1/2 x 11"
- 2 pieces of cardboard tube, 5-1/2" long, 1-1/2" diameter
- 1 sheet of glass or transparent plastic 5-1/2 x 11"
- 12" of stiff wire
- 1 birthday candle, tape

Cost: 5¢

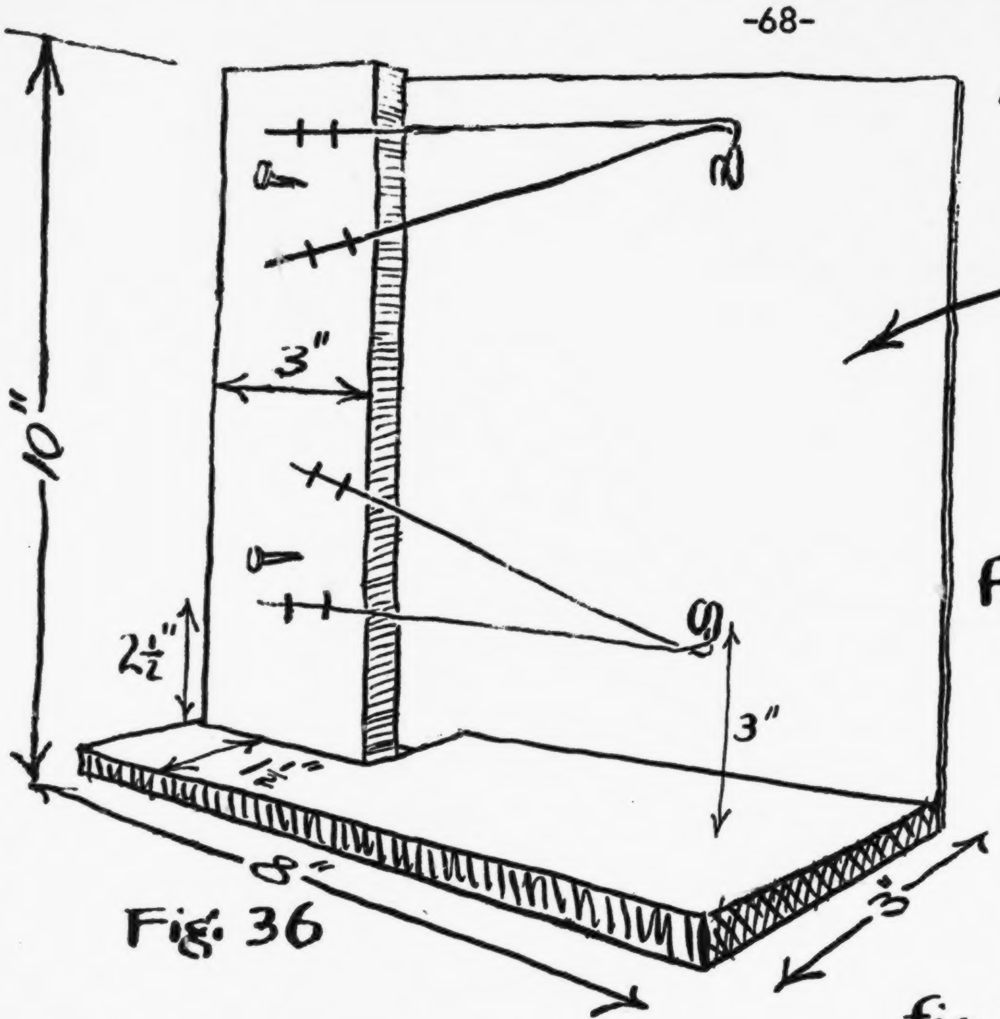

10"
3"
2½"
1½"
3"
8"
3"

Fig. 36

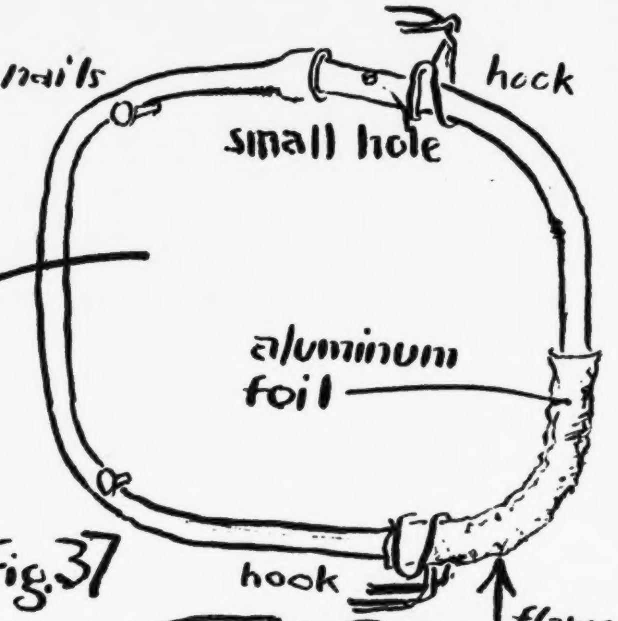

nails
hook
small hole
aluminum foil
hook
flame

fig. 37

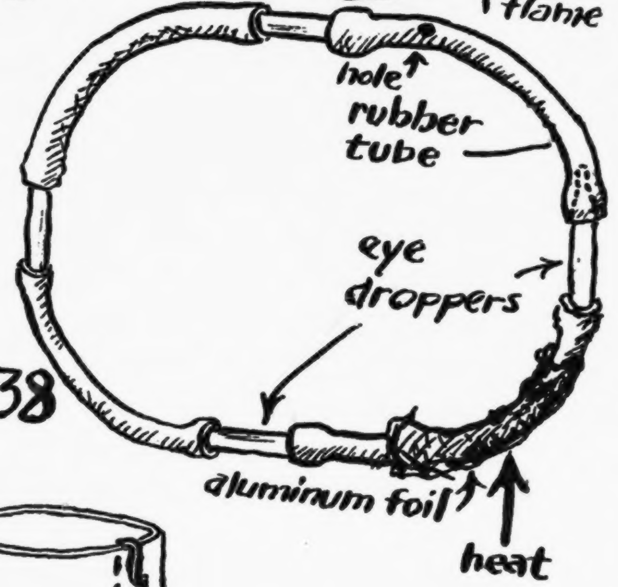

hole
rubber tube
eye droppers
aluminum foil
heat

fig. 38

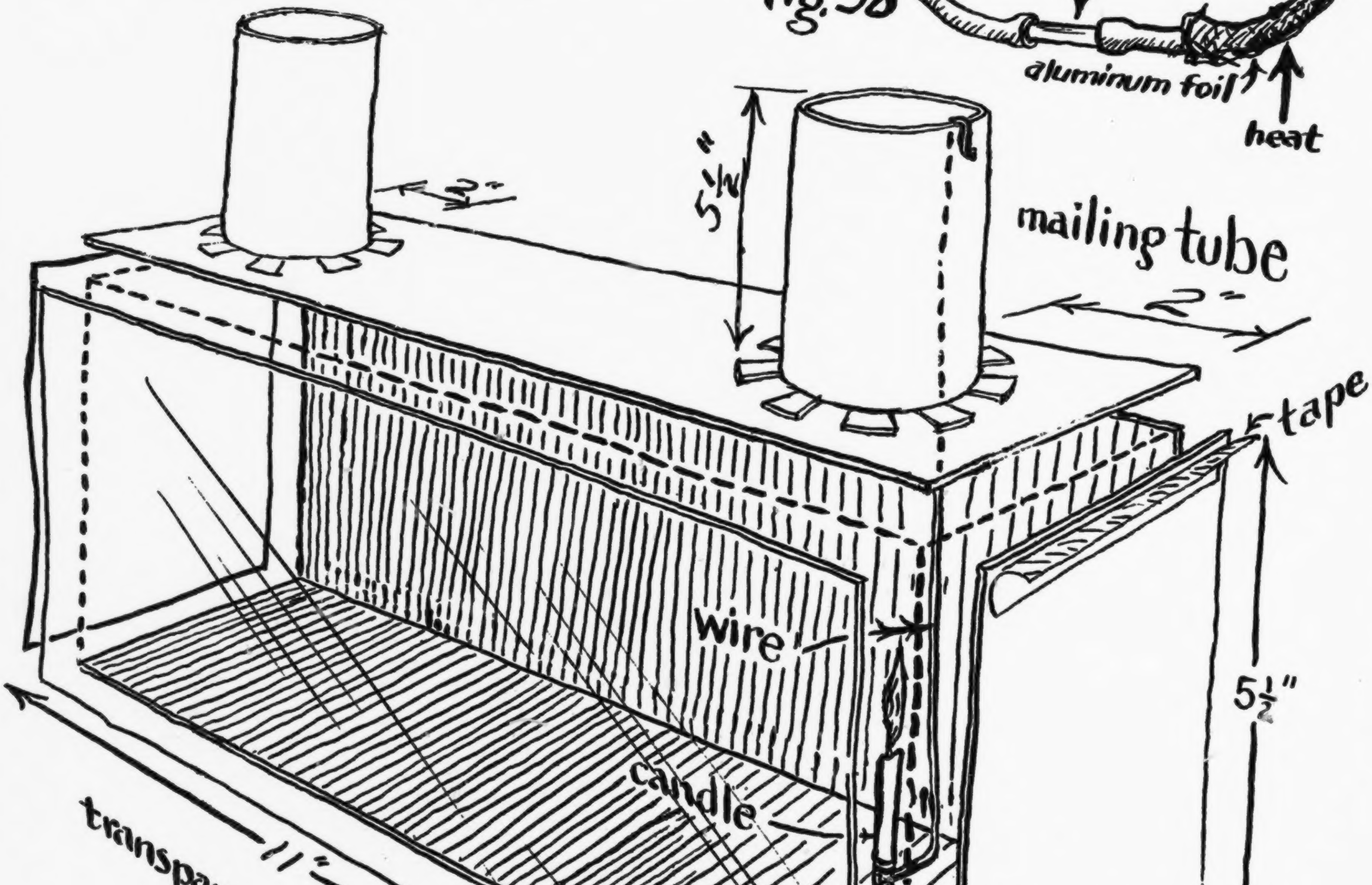

5½"
½"
mailing tube
2"
tape
wire
candle
11"
transparent front
5½"
3"

fig. 39

17. Convection Clouds.

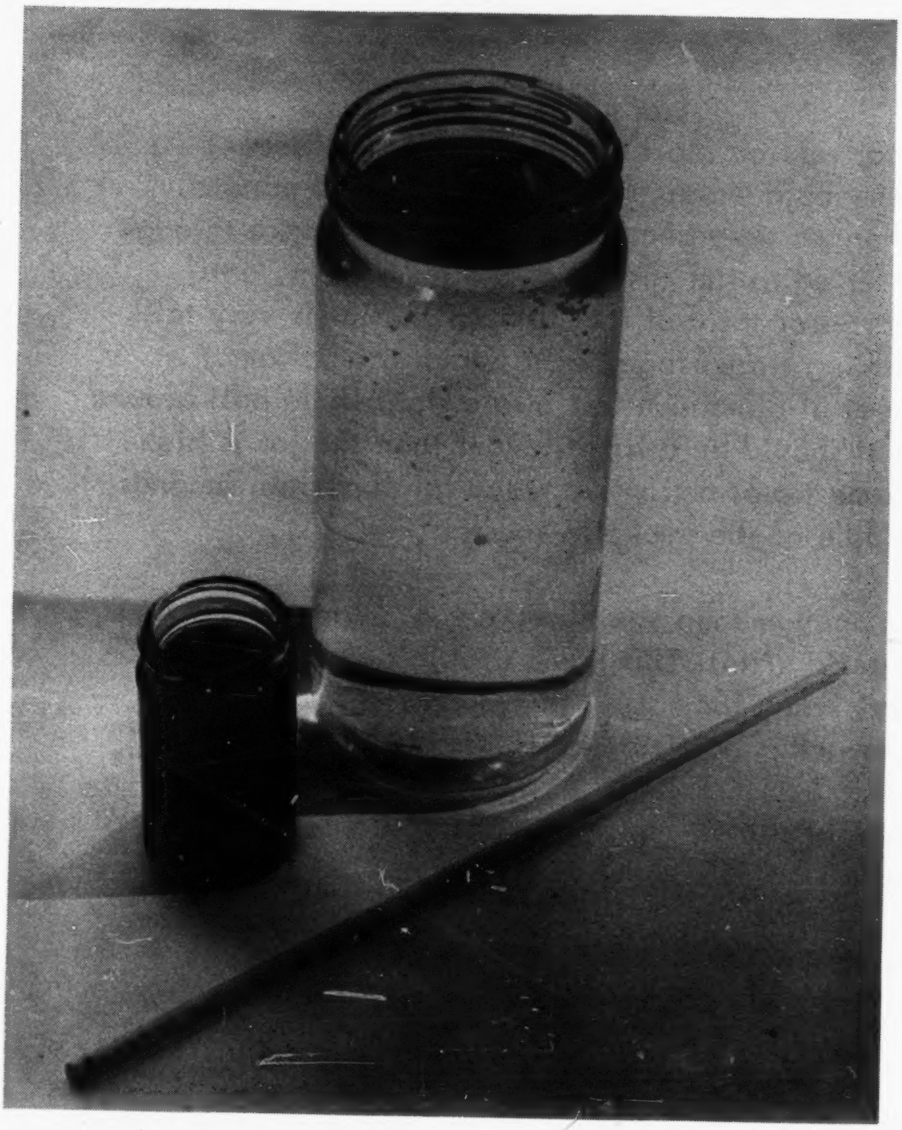


Plate 22

When the dew point is reached in ascending columns of air, cumuliform clouds appear.

a) Some of the characteristic shape and motion of cumuliform clouds can be reproduced in the laboratory, though in reverse direction. First we make a concentrated solution of table salt in water and dye it with ink or other coloring matter, so that it becomes opaque. We need only a small quantity, about 1/8 of a cup; it is best to make this solution in a narrow bottle so that we get a long column of it. We need a tall glass jar or jug, which we fill with water. Then we dip a thin drinking straw into the solution, close the top of the straw with a wet finger, and let the solution flow into the water, holding the straw in a vertical position with the lower end directly on the water surface.

1. Why does the salt solution sink in the water? 2. What are the similarities and the differences between the inverted "cloud" in the water and real cumulus clouds? Incidentally, the "clouds" can be seen rising, if we look at them in a mirror as shown in Fig. 40. The clouds can also be projected on a screen.

b) Another type of "convection clouds" can be made by first filling a tall glass jar with very cold water, letting it stand for a minute, and pouring it out again. Then we very gently blow cigarette smoke through a drinking straw, which is inserted to the middle of the jar bottom, until the smoke fills the lowest quarter or third of the jar. (If the jar is very tall, we may have to tape two drinking straws together to reach the bottom.) Now we crumble a 2 x 2" sheet of aluminum foil into a tight little ball around a piece of thread or string that should be a little longer than the jar is high. This ball we hold over the flame tip of a lighted match for about ten seconds and then lower it into the middle of the smoke in the jar (Fig. 41).

3. Describe and explain the phenomenon you observe. 4. Why do we first fill the jar with cold water? (Hint: This has a double purpose.) Try the experiment with a dry, warm jar.
Note: Experiment 23 also shows this convection effect.

Material: a) One teaspoon of salt
A small bottle
Water, ink
A tall glass jar or jug
A thin drinking straw or glass tube
A mirror

b) A tall glass jar
Aluminum foil, 2 x 2"
12" thread
Smoke source (cigarette)
A drinking straw

Cost: 20¢

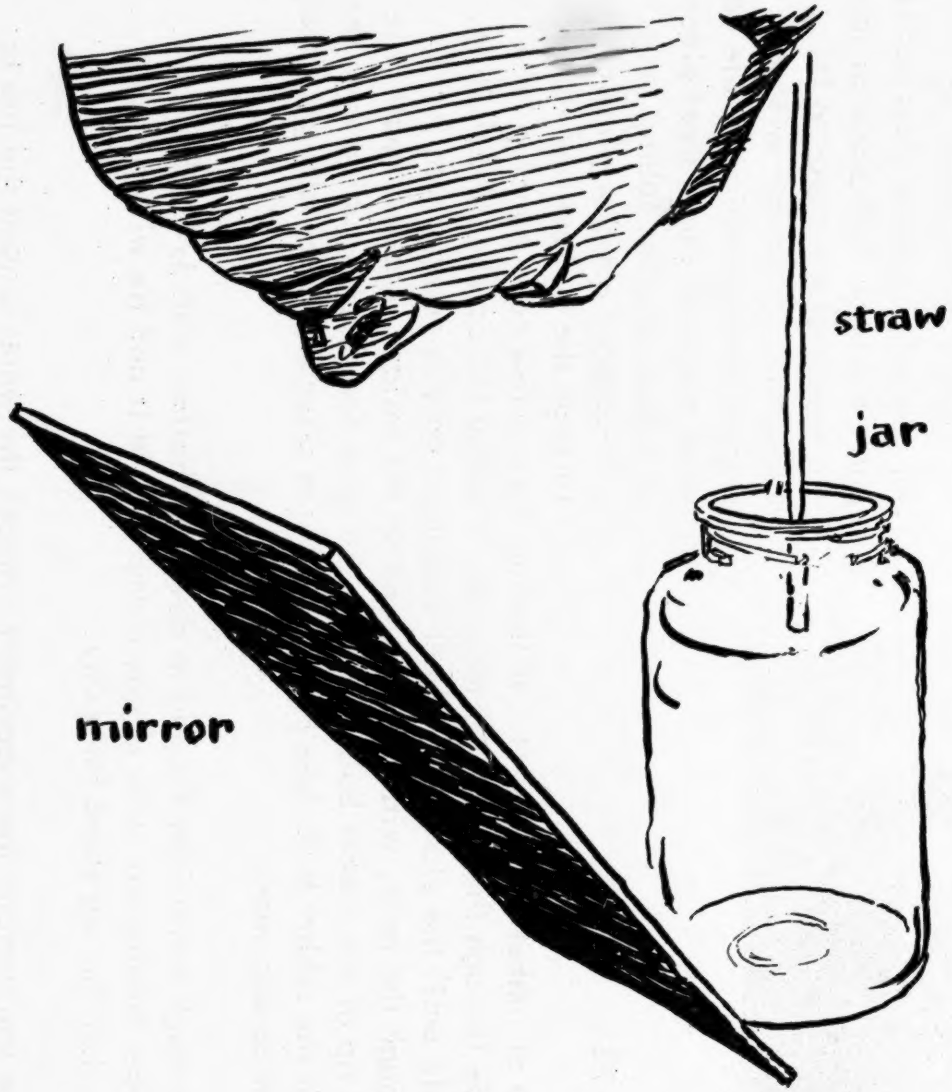

straw
jar
mirror

fig. 40

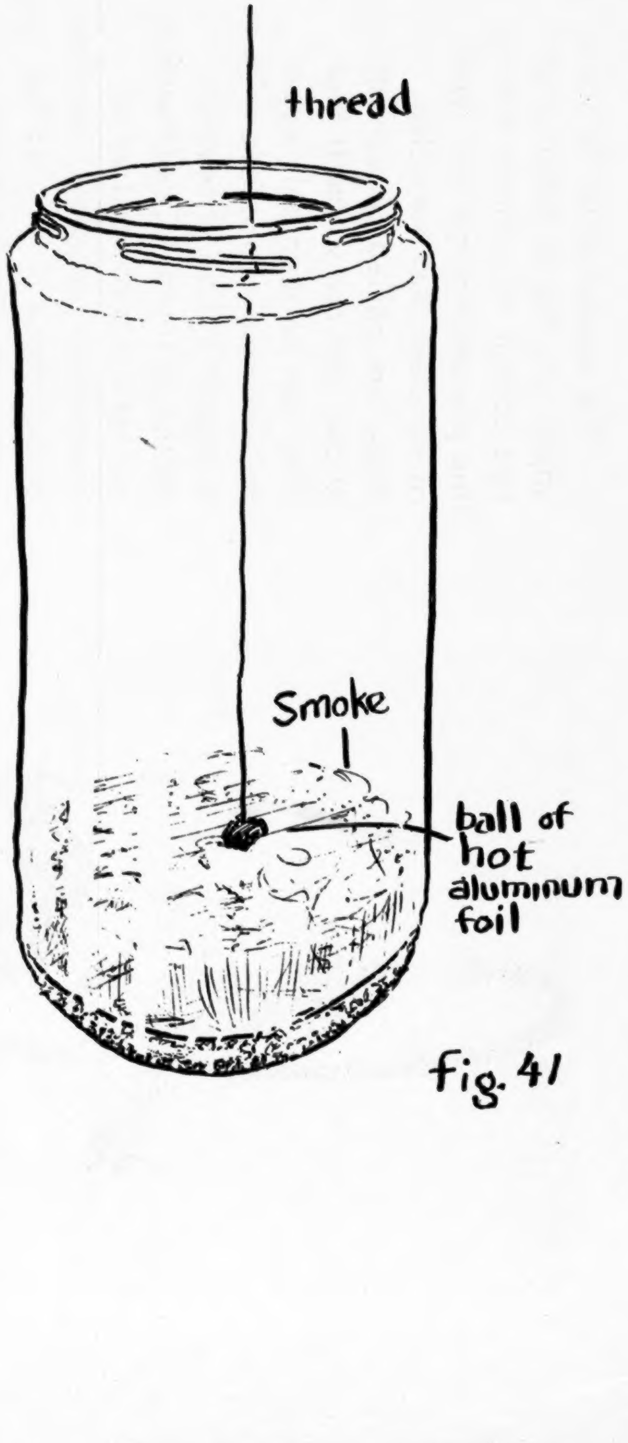

thread
Smoke
ball of hot aluminum foil

fig. 41

18. Fog and Condensation Nuclei

The condensation of water vapor into fog or cloud droplets cannot take place without the presence of certain types of minutest dust particles. These are called condensation nuclei and are so small that they can be seen only under an electron-microscope with a magnification of several thousand times. Condensation nuclei are produced by all combustion processes, whether or not smoke is visible; the spray from the ocean also produces condensation nuclei when the droplets evaporate leaving minute salt particles suspended in the air.

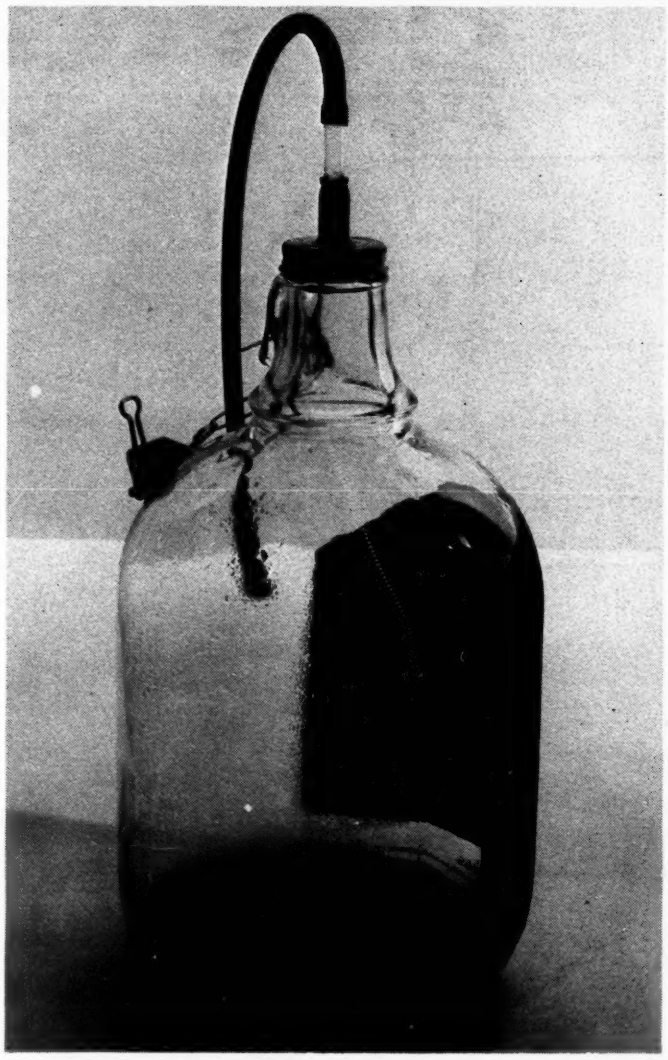


Plate 23.

Take a gallon glass jug (or any other smooth glass bottle), paint the back half black or tape a piece of black paper to it. Close the jug airtight with a stopper through which a hole has been punched; put a short piece of copper or glass tubing (e.g. eye-dropper glass or plastic tube) through the stopper and fasten a 6 to 10" piece of rubber tubing to it. If the jug has a screw cap, punch a hole from the inside through the middle of the cap including the cardboard disk in it. Widen the hole until the elongated rubber bulb from an eye dropper can just be squeezed through the hole, with the open end on the inside. Make a small hole in the closed tip of the rubber bulb and push the glass (or plastic) tubing from the inside through the rubber bulb (see Fig. 42). If the assembly is not airtight, close the leaks with candle wax.

Fill enough water into the jug to cover the bottom with 1/4" of water. Pinch the rubber tubing shut with a hose clamp or fold it and tie with a strong rubber band. Let the jug stand for a day.

Before you perform the experiment, swoosh the water around the jug to clear away dew that will have formed on the inside. Then shine a strong light beam from the side through the jug, while you look toward the black background.

It is best to have the room darkened or perform the experiment in a dark corner. Now open the rubber tubing, suck air out of the jug, and pinch the tubing shut. Observe what takes place in the jug. Make a mental note of the density of the fog and of the size of the droplets. Now light a match and hold the tip of its flame to the end of the rubber tubing; unclamp the tubing and let the fumes from the flame together with room air flow into the jug. 1. What happened to the fog? Now suck again air out of the jug and observe. 2. What is the fog density now as compared to the first fog formed after the jug had been standing closed for a day? What is the comparative size of the fog droplets? Let the air back into the jug and you will see the fog disappear. Repeat the experiment and you will note that the nuclei are still in the jug, producing fog, as soon as you suck out some air.

Most of the nuclei, but not all, can be removed from the jug by letting it stand for many hours, during which the nuclei diffuse to and adhere to the wall of the jug, as well as slowly fall into the water surface.

Material:
One gallon glass jug
One stopper (or screw cap)
One eye-dropper with glass or plastic tubing
Six to 10 inch rubber tubing to fit the eye dropper
Rubber band, black paint or piece of black paper
Bright light source

Cost: 30¢ (including jug)

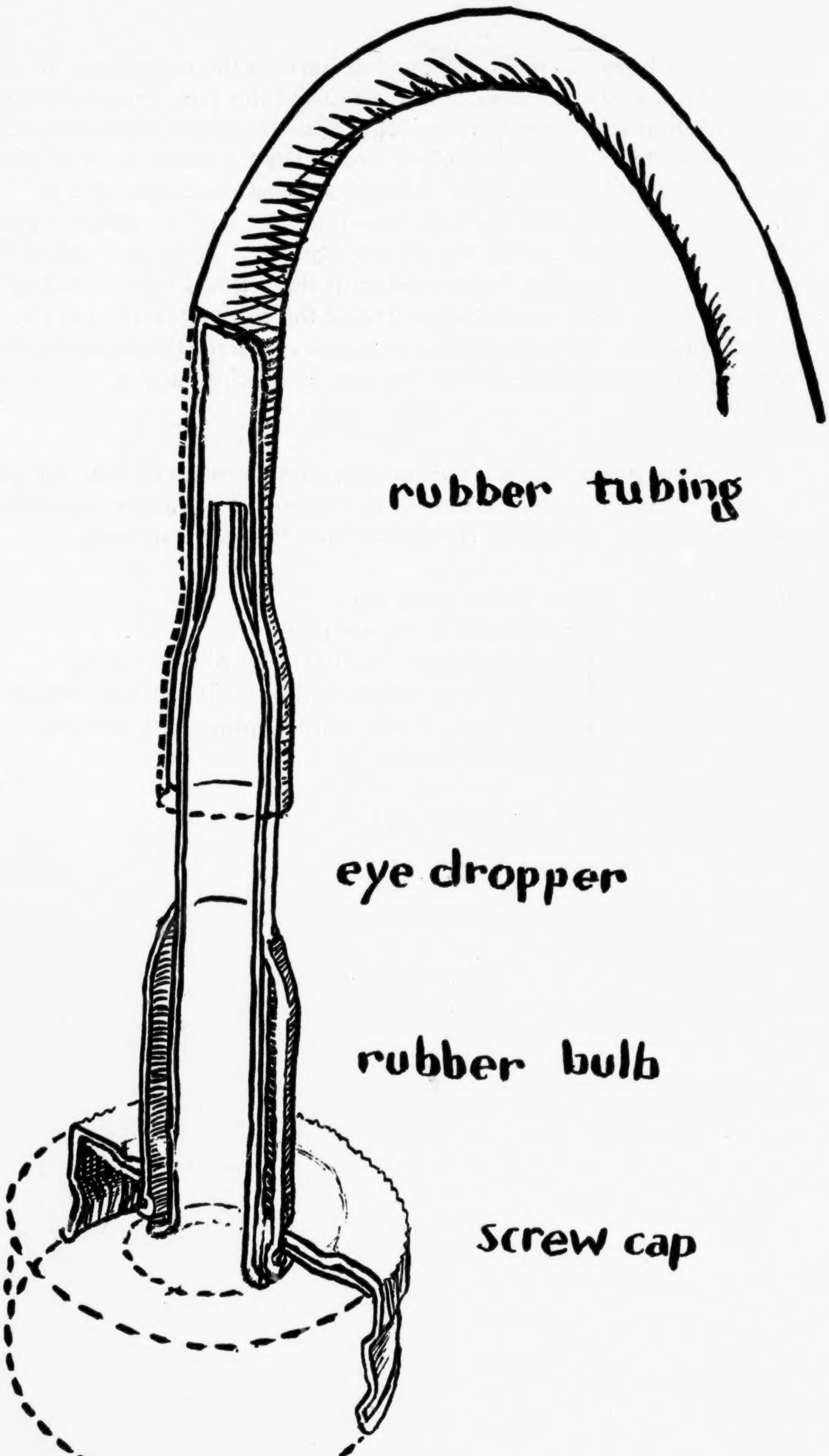

rubber tubing
eye dropper
rubber bulb
screw cap

Fig. 42

19. Hydrologic Cycle.

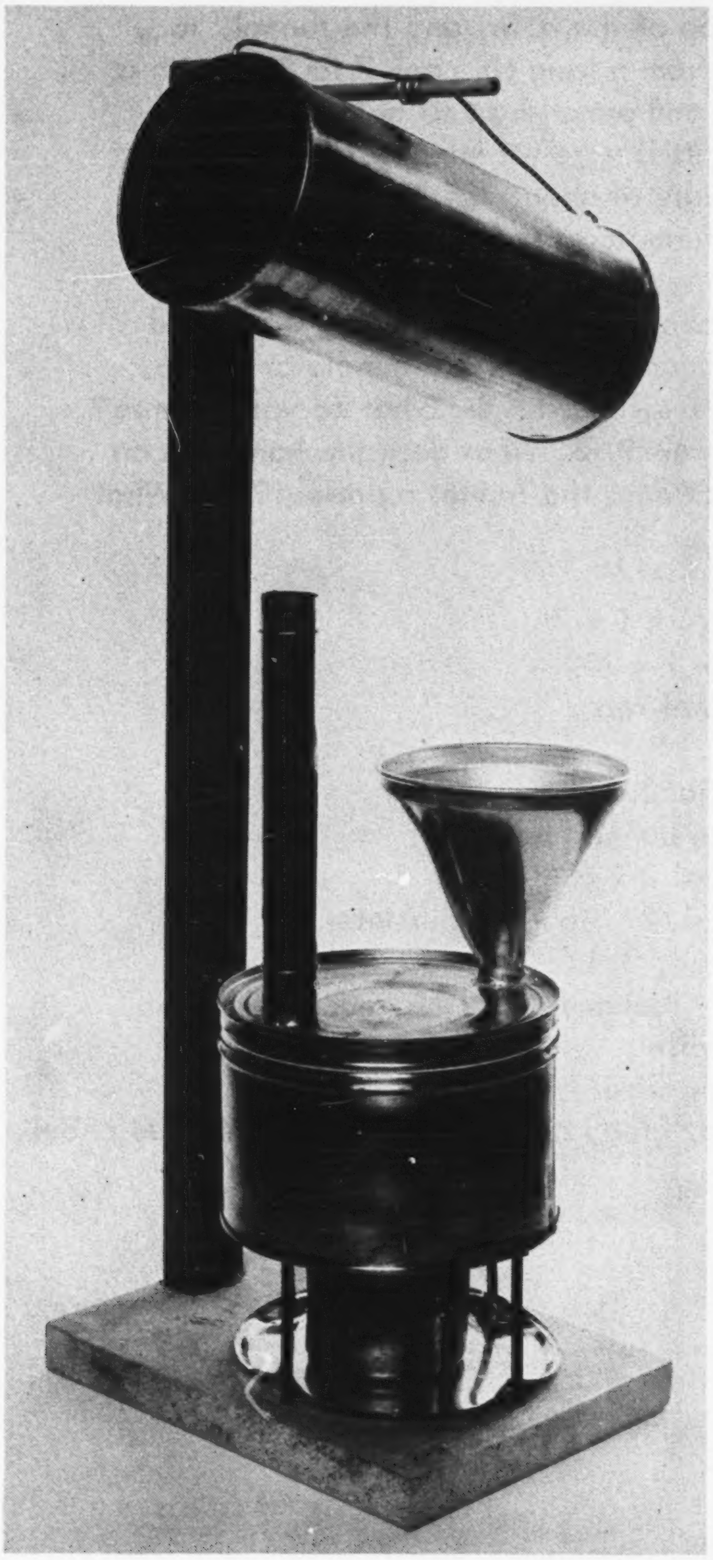


Plate 24.

The water in the atmosphere undergoes a continuous cycle: Water evaporates from the oceans, lakes, rivers, etc., and the water vapor in the atmosphere eventually condenses into clouds. Some of the clouds produce precipitation which falls on the oceans and continents. The water that falls on the continents gathers in rivers and lakes and seeps into the ground. Some of this water again evaporates directly, some of it flows back to the seas where it also evaporates again.

For a demonstration model of this hydrologic cycle we need a piece of wood, 3/4 x 6 x 7"; in the middle of one of the short edges we glue a stick of wood, 1 x 1 x 20", at whose upper end we fasten a 6" piece of 1/4" dowel rod to extend out over the base (Fig 43.). Into the base we hammer four heavy 3" nails to make a support for a coffee tin can, 3-1/2" high and 5" diameter. (This is essentially the "stove" described in Section III,E; if we have such a heating stand, we can simply set it on the base, but then we have to make the upright stick correspondingly longer) Between the nails we put a can top or large jar lid as trivet on which we fasten a short piece of candle or set a Sterno-heat can.

Into the coffee can lid we punch holes on opposite sides near the rim. The one hole we widen so that we can stick a metal funnel through it that has a rim diameter of about 3 to 4". The other hole we widen to a diameter of 1/2". Then we roll a sheet of tin-can metal, 3 x 6", into a tube of 6" length and about 3/4" diameter and tie it near the top and bottom with wire. The tube is fastened with liquid (or hot) solder on top of the hole, and the funnel, too, is soldered into the can lid (Fig. 44). From a long tin can, 7 to 8" , with a diameter of 3-1/2", we remove the top and punch a small hole through the rim of the bottom. With a 10" piece of stiff wire we hang this can so from the dowel that the can is tilted at an angle of about 20° from the horizontal with the bottom over the middle of the funnel, as shown in Fig. 45.

Now we fill the coffee tin can about half full of boiling water and put several pieces of ice in the hanging can and light the candle or sterno. After a few minutes the hydrologic cycle will start. 1. What do you observe? 2. What does the water in the can represent? 3. What does the hanging can represent? What the ice in it? 4. What does the funnel represent? 5. What does the candle or sterno represent?

Material: One piece of wood, 3/4 x 6 x 7"
One stick of wood, 1 x 1 x 20"
A 6" piece of 1/4" dowel rod
Four 3" nails
A tin-can lid or large jar lid
A short candle or sterno canned heat
A piece of tin-can metal 3 x 6"
One coffee tin can, 3-1/2" high, 5" diameter
One tin can 7 to 8" high, 3-1/2" diameter
One metal funnel 3 to 4" diameter
Two 4" pieces of thin wire
One 10" piece of heavy wire
Liquid (or other) solder, glue, boiling water and a few ice cubes.

Cost: 50¢

fig. 44

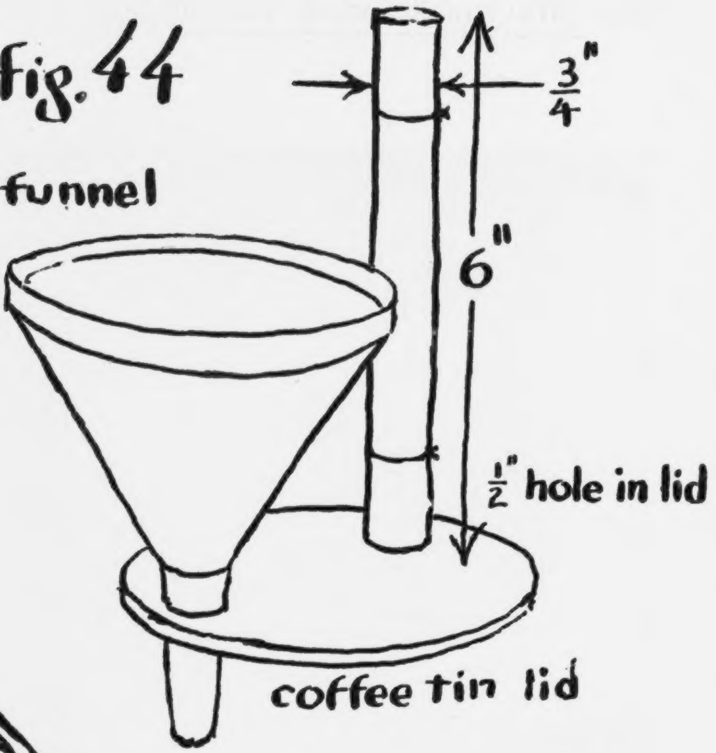

3/4"
funnel
6"
1/2" hole in lid
coffee tin lid

fig. 45

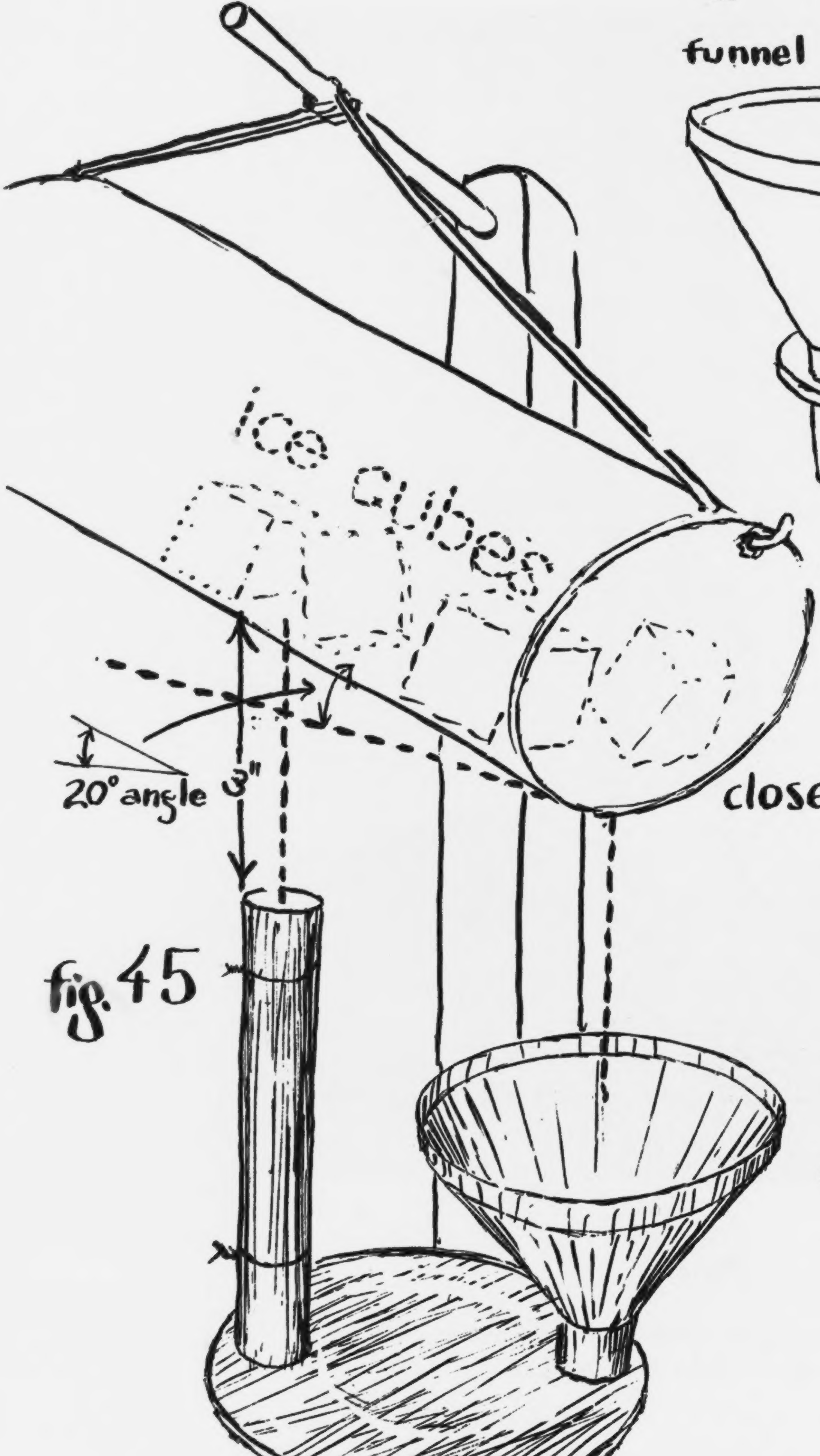
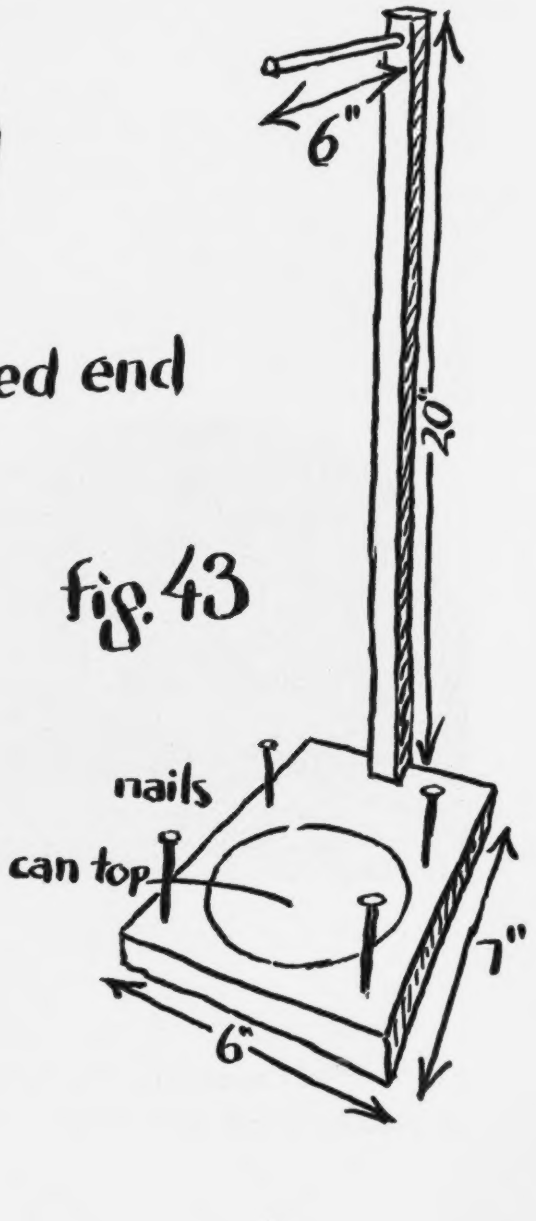

ice cubes
20° angle
3"
closed end

fig. 43


6"
20"
nails
can top
7"
6"

20. Effect of Raindrop Size on Soil Erosion.

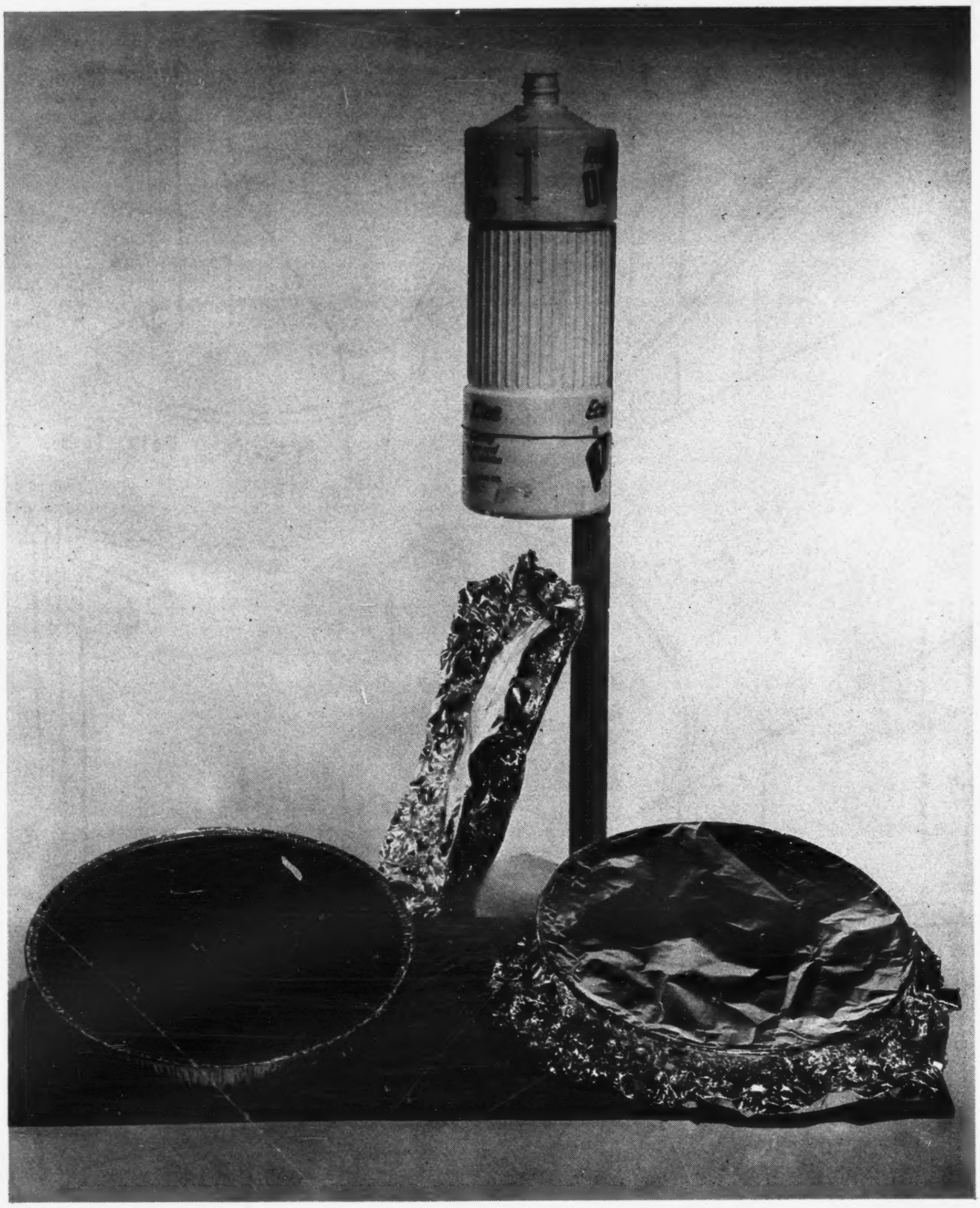


Plate 25.

Soil erosion, which has always been an agricultural problem, is caused by wind and water. Rain falling on sloping bare ground can remove a considerable amount of valuable top soil in a short period of time. To show the action of raindrops of different sizes, we proceed as follows:

We fill two 8" pie plates (of aluminum or other metal) with a 1/2" layer of very fine, dry soil which we have sifted through a piece of window screening. If the soil contains a great deal of clay, it is better to mix some fine sand with it. The top of the soil layer is smoothed with a small piece of cardboard. The plates should be propped up so that they have a slope of about 1:3. It is easiest to set them on a piece of 1/8" or 1/4" plywood, 6 x 20", along one edge of which we have nailed a strip of wood, 3/4 x 2 x 20".

To prevent the plates from sliding, we hammer two nails for each plate from the bottom side of the board as shown in Fig. 46. Each plate is covered with a sheet of aluminum foil, 10 x 10".

Raindrops of different sizes are produced with a tall plastic bottle (detergent container), preferably of quart size, into which we push, about 1/2" from the bottom, a fine pin or sewing needle at an angle of about 45° from the vertical; a nail (such as a 1" brad) is similarly pushed through the bottle at another place (see Fig. 47). We fill the bottle with water to the top and test the "rain" issuing from the two holes. The pin-hole should produce a very fine spray of drops of about 1/32" or less, whereas the nail-hole should produce a spray of relatively large drops of 1/8" or more. If the holes are not large enough, we widen them; if they are too large, we cement them shut again or cover them with scotchtape and make new holes.

Since the amount of soil erosion depends also on the amount of rain, we must make sure that the same amount of water is used for the production of the two different "rains". For this we cut with a sharp knife a slot near the top of the bottle, about 1/4" wide and 1-1/2" long, make two water-level marks 1" apart on each side of the slot, and cover the slot with scotchtape, or cement an appropriate piece of clear plastic over the slot (Fig. 47). We also cover the two holes near the bottom of the bottle with scotchtape. The bottle is then wired or taped to the top of a 6ft. stick of wood, so that the height from which the drops fall onto the soil is the same in both cases.

The experiment is best performed outdoors at a wind-protected place, or indoors where water on the floor does not matter. We cover both plates with the aluminum-foil sheets, fill the bottle with water open one of the holes and let the spray fall on one of the covered plates (Fig. 46). When the water level in the bottle reaches the top mark, we quickly uncover the plate and let the "rain" fall on the soil, until the water level in the bottle reaches the lower mark, when we quickly cover the plate again. This process is repeated with the other hole and the other plate.

1. Observe the effects of the "rains" and describe them in terms of pitting and splashing of the soil.

Material:	Two aluminum pie plates Fine soil or soil-sand mixture A piece of 12 x 12" window screening 1/8" plywood, 6 x 20" A 6-ft. stick or pole of wood Small piece of cardboard Two sheets of 10 x 10 " aluminum foil One plastic bottle (detergent container), quart size Scotchtape, nails, water One strip of wood, 3/4 x 2 x 20"
Cost:	40¢

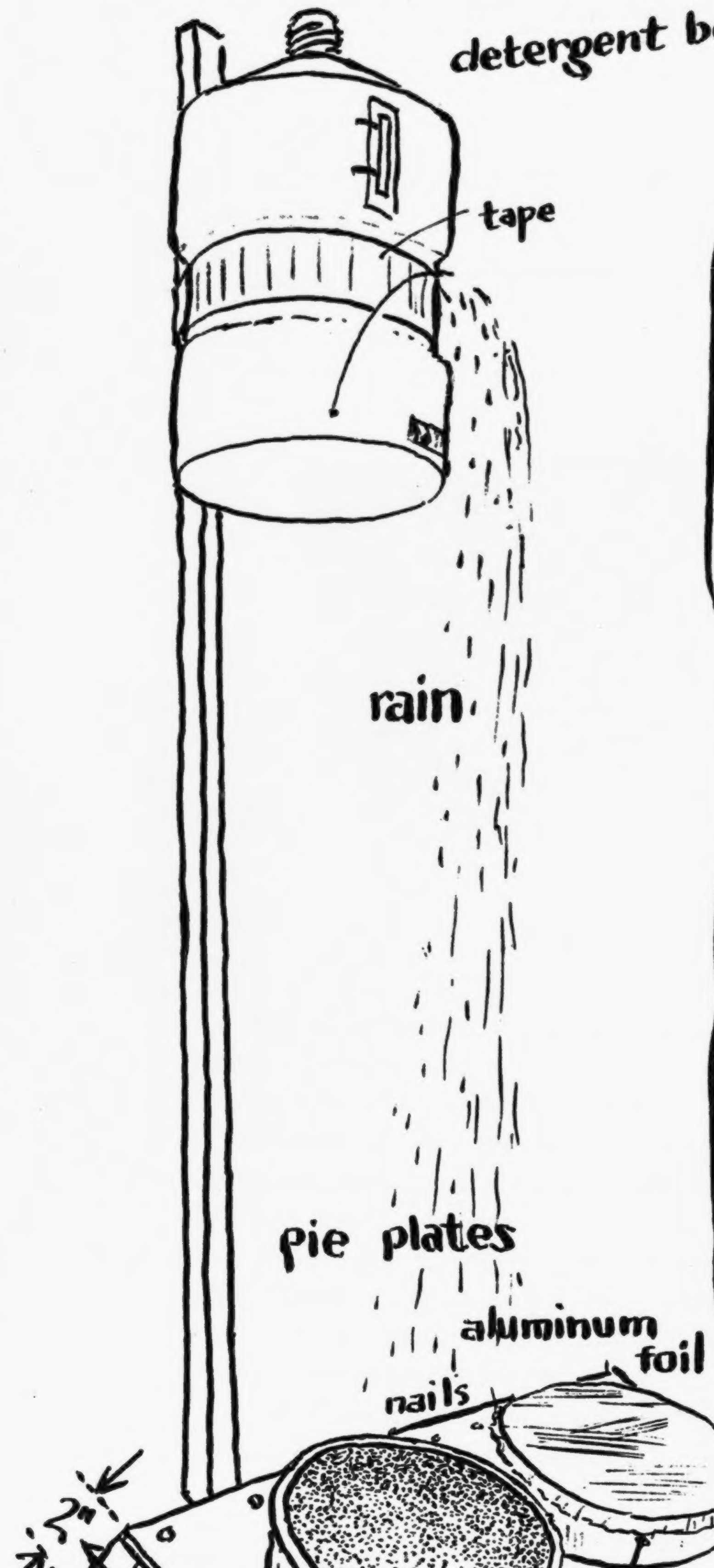

detergent bottle
tape
rain
pie plates
aluminum foil
nails
2"
6"
nails
20"

fig. 46

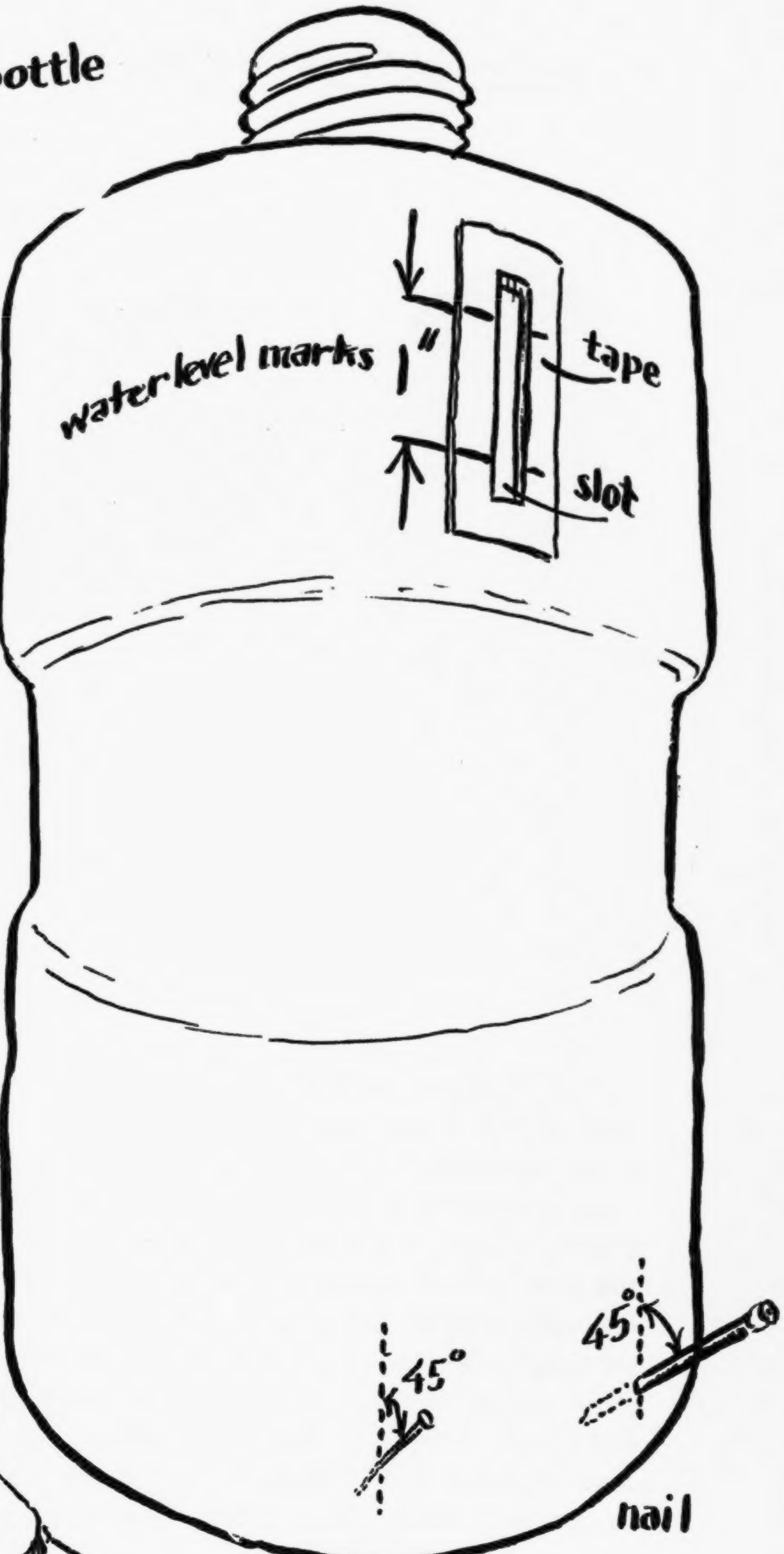

water level marks
1"
tape
slot
45°
45°
nail
pin

fig. 47

21. Mechanical Equivalent of Atmospheric Stability and Instability.

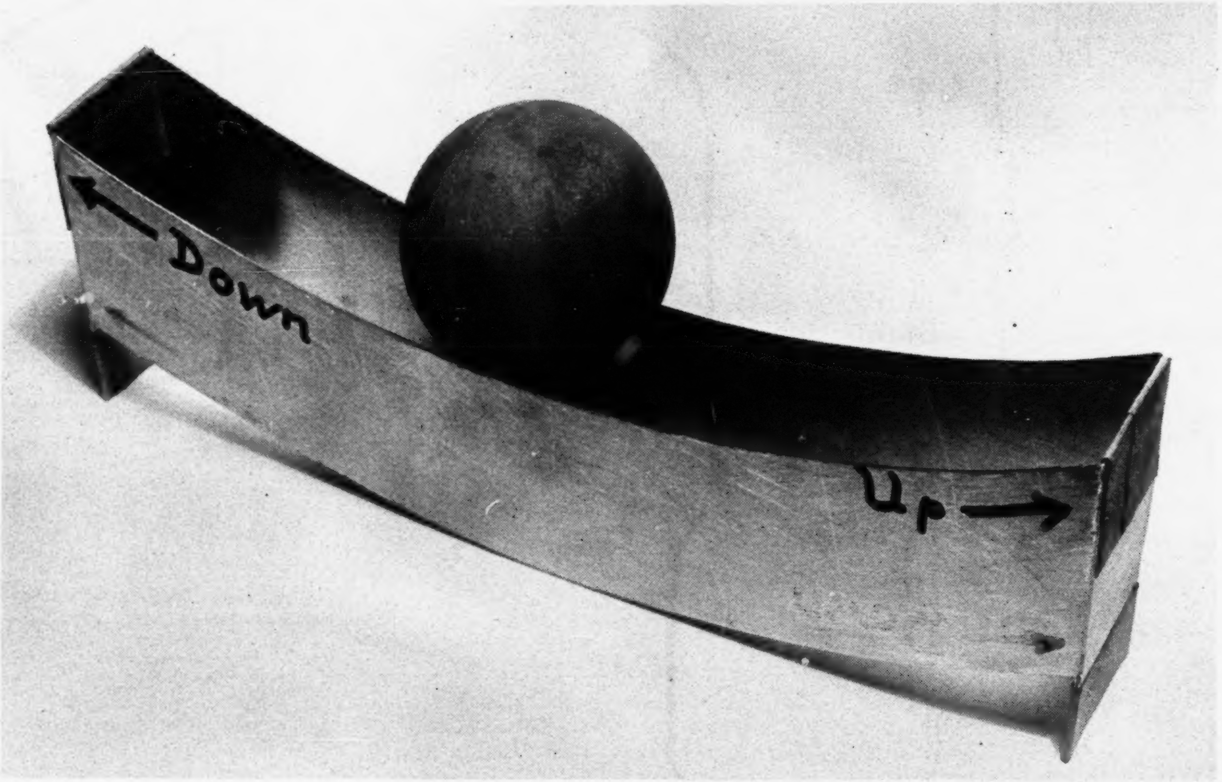


Plate 26.

Stability or instability of the air in the troposphere is an important characteristic that determines, to a large extent, what kind of weather phenomena may occur. For example, cumuliform clouds, thunderstorms, shower-type precipitation occur in unstable air, whereas stratiform clouds, steady precipitation, fog occur in stable air. All these phenomena depend on either the presence or absence, respectively, of vertical air currents. These currents are supported in unstable air, suppressed in stable air. If an air parcel is vertically displaced (such as by air moving up or down a mountain slope) under stable conditions, it tends to resist the displacement and to return to its original level. Under unstable conditions, the air parcel tends to assist vertical displacement and to move farther away from its original level, once it is displaced. This can be shown by a mechanically equivalent model as follows.

Cut two pieces of stiff cardboard (for greater durability the model can be constructed from sheet metal or wood), each in the shape shown in Fig. 48. The dimensions depend on the desired size of the model. The proportions recommended are: B ten times as large as A, and C twice as large as A, in Fig. 48. The curvature shown is best a flat circular arc. The length of A should be approximately 1/2 the diameter of a small ball (rubber or plastic), or equal to the inner length of a large empty spool of thread as shown in Fig. 49. For example, if we have a ball of 2" diameter, A=1", B=10", C=2".

Each of the two pieces of cardboard are bent back along the dotted lines, and the two are stapled, glued, or taped together to make a trough (Fig. 49).

Considering that "up" and "down" are relative directions (compare, e.g., these directions for people living on opposite sides of the globe), we can mark the direction to the left by "Down", to the right by "Up"; or reverse. We then turn the model upside-down and mark again as shown in Fig. 50.

Now we place a ball or spool of appropriate size in the center of the trough (position 1). The ball represents a parcel of air, the trough represents the air surrounding the parcel. 1. If the parcel is displaced "Up" (about half the distance to the end of the trough) and let go, what happens? What happens, when the parcel is displaced "Down"? 2. Does this represent the stable or the unstable case?

We now turn the model to position 2 and balance the ball in the middle so that it will stay put. Then we give the parcel of air a small displacement "Up" or "Down" and let go. 3. What happens? 4. Does this represent the stable or the unstable case? 5. If we perform the same experiment by placing the ball or spool on a level table top, what will happen? 6. What would you call this condition? 7. If an actual air parcel were displaced up or down in the atmosphere under equivalent conditions, what would happen to the air parcel?

Material:	Cardboard A small ball or empty spool of thread Scotchtape, glue, or staples
Cost:	10¢

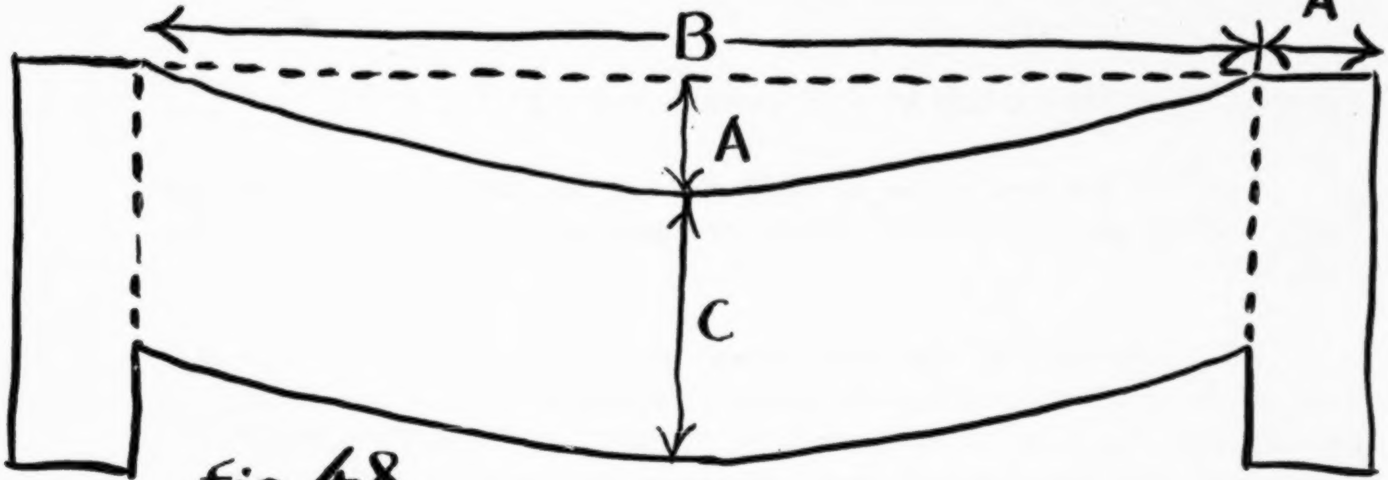


fig. 48

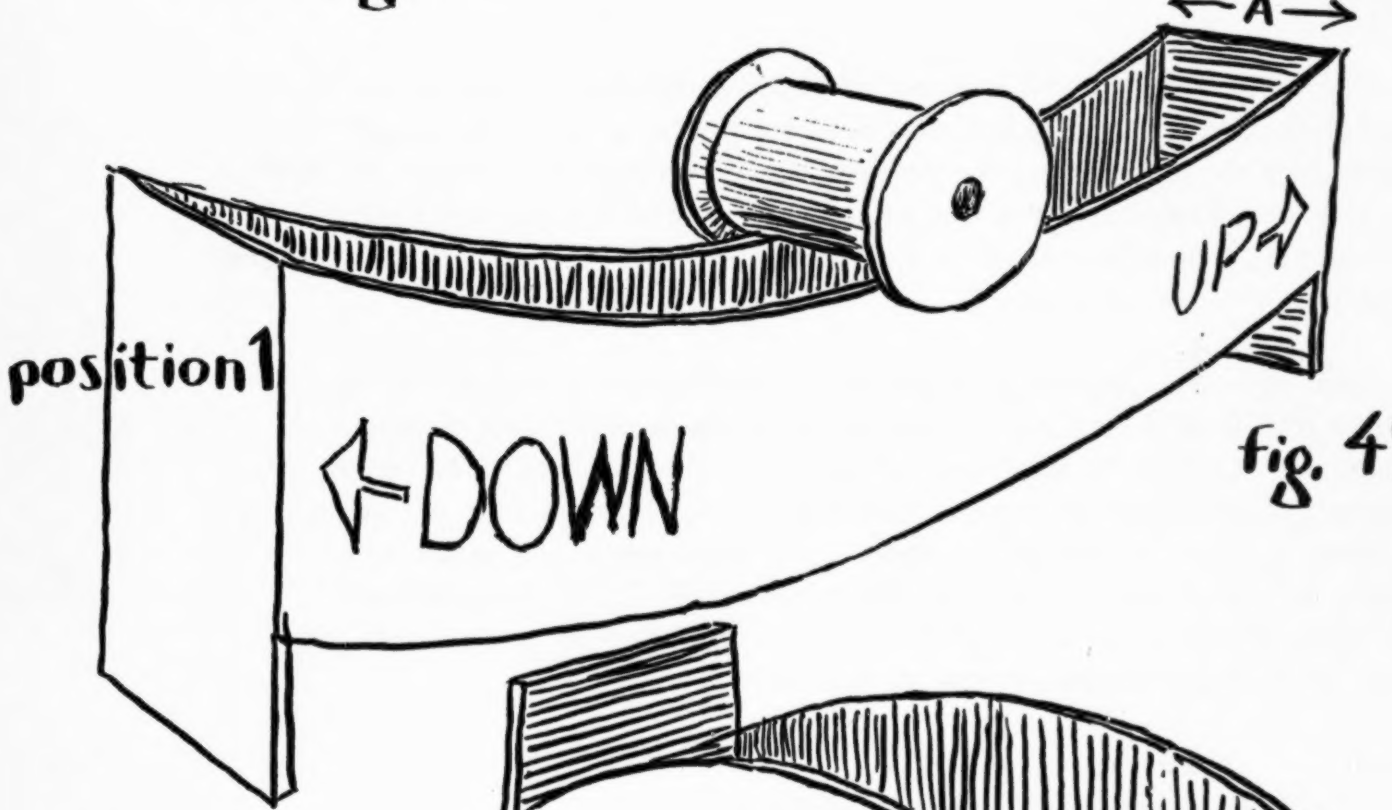

A
UP
position 1
DOWN

fig. 49

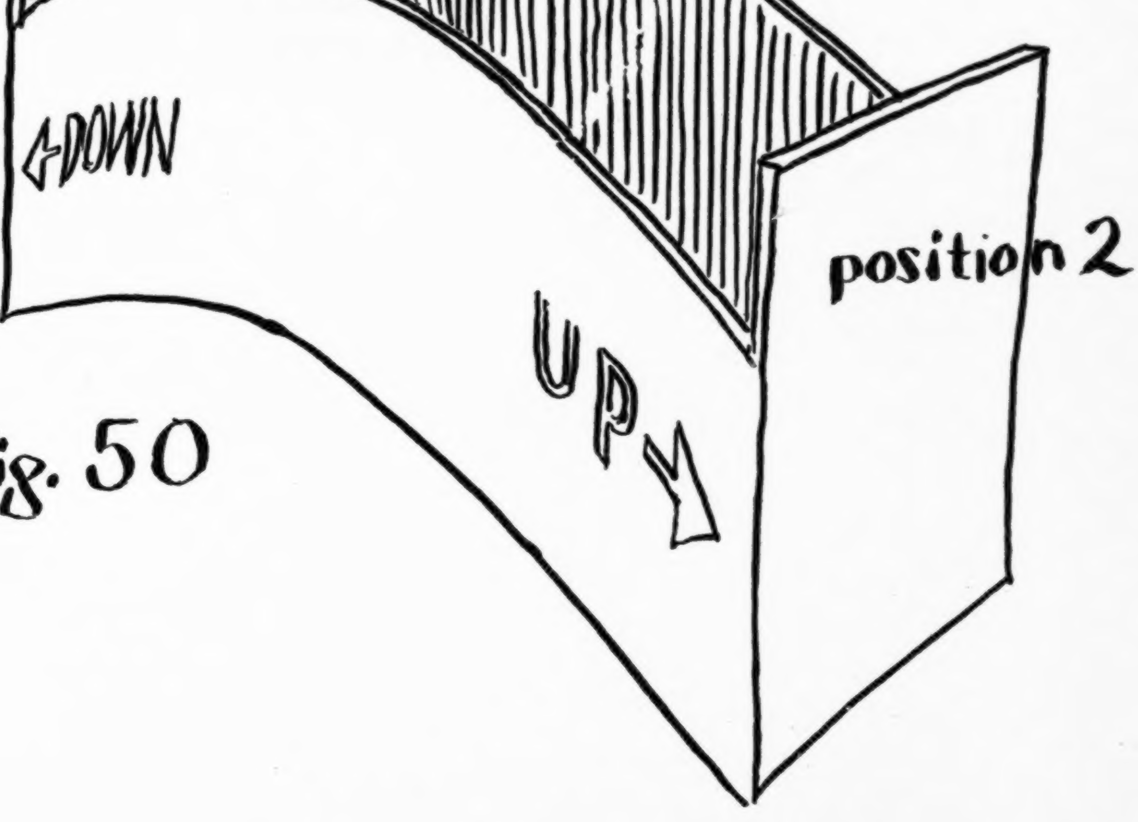

DOWN
position 2
UP

fig. 50

22. Temperature Stratifications.

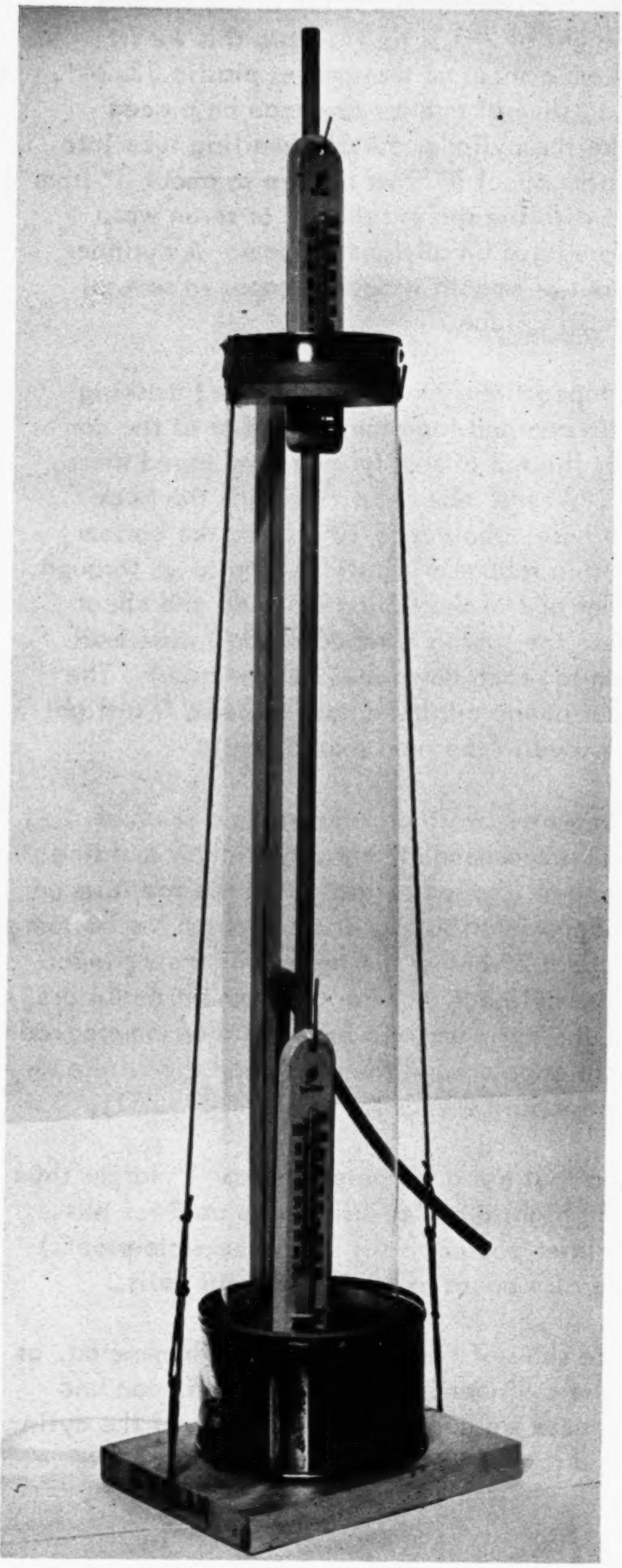


Plate 27.

Atmospheric stability and instability (see Experiment 21) are caused by different temperature changes with height. Roughly, if the temperature decreases by more then 1/2° F per 100 ft. height increase, the air layer is unstable; if the temperature decreases by less than this amount, the air layer is stable. Particularly strong stability is produced, when the temperature is the same at various heights, in which case the air layer is said to be isothermal; the most stable case exists, when the air temperature increases with increase in height, a condition called inversion.

The various conditions of temperature stratification can come about in various ways. For example, if the air is cooled near the ground by contact with a cold earth's surface, the air aloft will not be affected and an isothermal condition or even an inversion will be established. By contrast, when the earth's surface is warmer than the air, the air in contact with it will be warmed, while the air aloft will remain cool, so that the temperature will drop rapidly with increase in height. These conditions can be demonstrated in the following manner.

Any tall container can be used for the experiment, but a long, transparent cylinder is best for the purpose. We cut the top out of a tin can, about 6" long and 4" diameter; then we cut a ring, about one inch wide, off the top of the can and the remaining portion of the tin can with the bottom we cut down to a height of 2-1/2 to 3". Into this we fit tightly a cylinder 24" long, made from a sheet of transparent plastic 13x24". If such a large sheet is not available, several smaller ones can be pieced together with tape. Or we can make the cylinder out of a mailing tube into which we cut a slot about 2" wide from about 3" from the top to about 3" from the bottom; this slot is then covered with transparent plastic or seran wrap which is taped to the tube, so that we have an airtight window. A cylinder can also be made by rolling a tube out of smooth wrapping paper in several layers and proceeding as with the mailing tube.

The seam of the cylinder is taped tightly with scotch tape(masking tape). We insert the tube into the tin can and tape them together at the can rim. The metal ring is then put over the top of the cylinder and taped there, to stiffen the upper end of the tube. At the tube seam, which is the back of the cylinder, we drill or punch a hole, about 9 to 10" above the bottom, just big enough for an 18" piece of thin rubber or plastic tubing to go through. We insert the tubing so that the lower end of the tubing is inside and about 1" above the bottom of the can; there the tubing is taped to the inside wall of the cylinder (this takes a thin arm to reach down into the cylinder) . The rubber tubing is taped to the cylinder at the entrance hole to make it airtight (see Fig. 51). This rubber tubing is used in the next experiment.

Now we fasten, with tape or wire, two thermometers to a stick of wood, 30" long; a 3/8" dowel rod is recommended, but any stick or molding will do. The thermometers are placed on the rod so that when the rod rests on the bottom of the can, the lower thermometer bulb is about 2" from the bottom and the upper thermometer bulb is about 2" below the top rim of the cylinder. The stick should be so placed into the cylinder that the thermometer bulbs are in the center of the cross section of the cylinder. To hold the thermometer rod in place, we wind a 7" piece of wire once around the rod, bend the wire ends over the top rim of the cylinder, and tape the ends to the sides (Fig. 51).

Now we find another tin can that has a diameter at least 1" larger than the cylinder can and is about 2 to 3" high; a coffee tin can be used for this. (Into this can hot and cold water is later poured, so it should be waterproof.) This larger can is held in the middle of a board of wood with four nails.

In the middle of two opposite sides of the board nails are hammered, as shown in Fig. 51. Then we place the cylinder in the middle of the can and make two hooks out of paper clips; these we hang over the top rim of the cylinder, tie a piece of string to each and rubber band to the other ends of the strings, and hang the rubber bands under slight tension over the nails in the sides of the board. This will hold the cylinder in place and prevent its toppling over, when the large can is filled with water.

Now we take a reading of the thermometers (which should read practically the same) and then pour ice water with small pieces of crushed ice into the outer can; the water level should not reach the tape on the inner can, to which the plastic cylinder is fastened. After 5 minutes we read again the two thermometers. 1. What is this temperature stratification called? Is this a stable or unstable condition? 2. What would this temperature difference be, if it were sustained over a vertical distance of 100 feet?

The cylinder is removed, the water can emptied, and the apparatus again assembled. Then we pour very hot water into the can, again to a level below the tape, and observe the temperatures after a few minutes. 3. Compute what the temperature change would be for a vertical distance of 100 feet. 4. Is this a stable or an unstable condition?

Save this equipment for the next experiment.

Material:
Two equal thermometers
A sheet of transparent plastic 13 x 24"
3/8" dowel rod, 30" long
One tin can 4" diameter, 6" high
One tin can 5" diameter or more, 2 to 3" high
Stiff wire, 7" long
Two pieces of wire, each 2" long (paper clip)
4 ft. of string
Two rubber bands
Piece of wood 3/4 x 6 x 7"
Six nails
Scotch or masking tape
18" of thin rubber hose or plastic hose.

Cost: $1.00 (including thermometers)

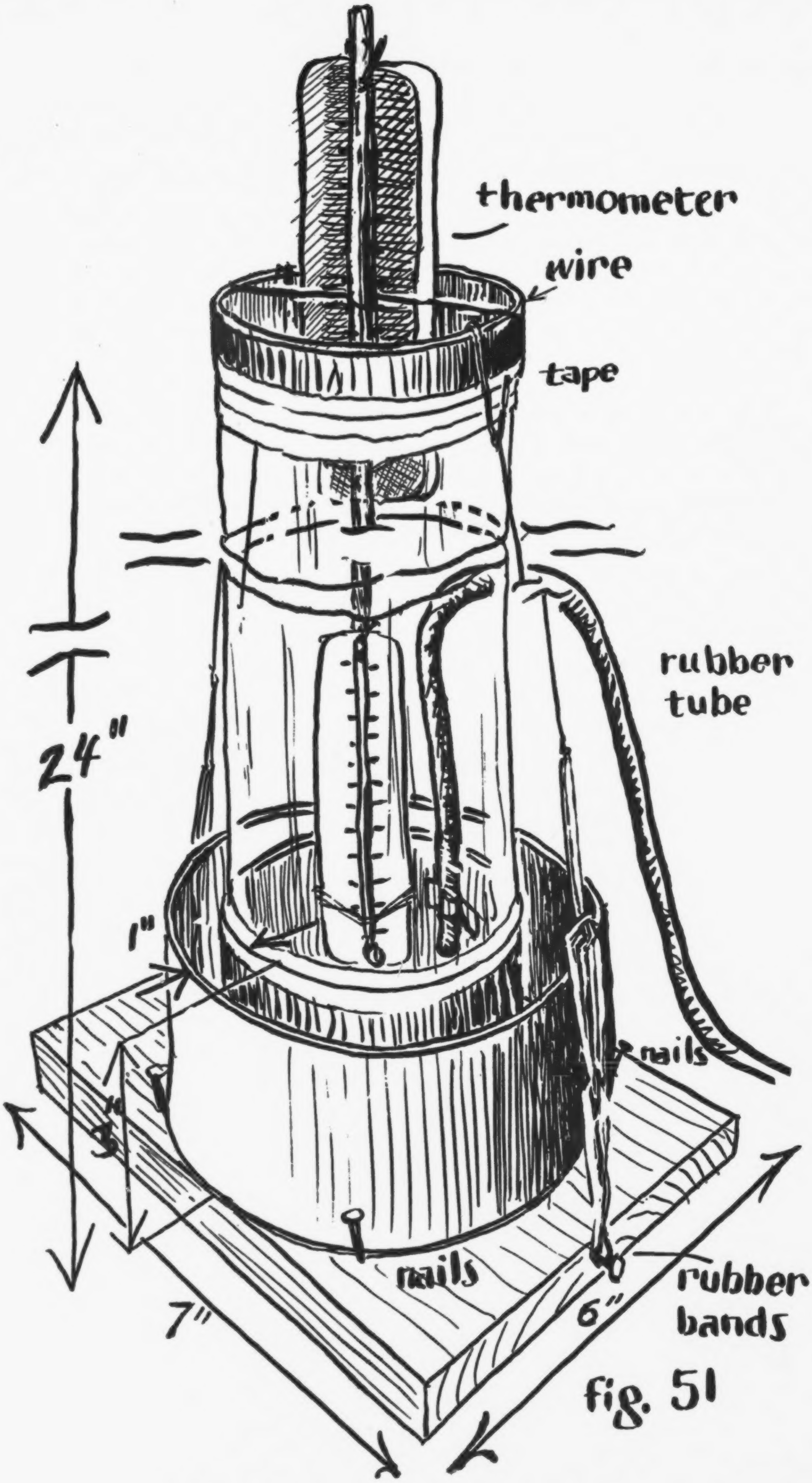

thermometer
wire
tape
rubber tube
24"
1"
3"
nails
nails
rubber bands
7"
6"

fig. 51

23. Effect of Temperature Stratifications on Air Pollution.

Under stable atmospheric conditions vertical currents are suppressed, so that smoke remains concentrated in the stable air layer; by contrast, the development of vertical currents in unstable air tends to disperse the smoke.

For demonstration of this effect the apparatus constructed in the preceding experiment is used in the same manner as before, but after a strong inversion has developed, we gently blow smoke through the rubber tubing into the bottom of the cylinder, until the smoke fills approximately 1/3 of the cylinder. The smoke soon comes to rest. We then exchange the iced water with hot water. Observe carefully the development of instability and the attendant behavior of the smoke. Note, how columns of heated air intermittently push upward, until the smoke emerges form the top of the cylinder.

These convection currents are typical of those that occur on a larger scale on a sunny afternoon (see Experiment 16). Describe your observations, including the temperature distribution in the cylinder when major movements of the smoke occur.

Material:	Apparatus constructed in Experiment 22. Smoke from cigarette or other source Iced water and hot water.

24. Mechanical Turbulence.

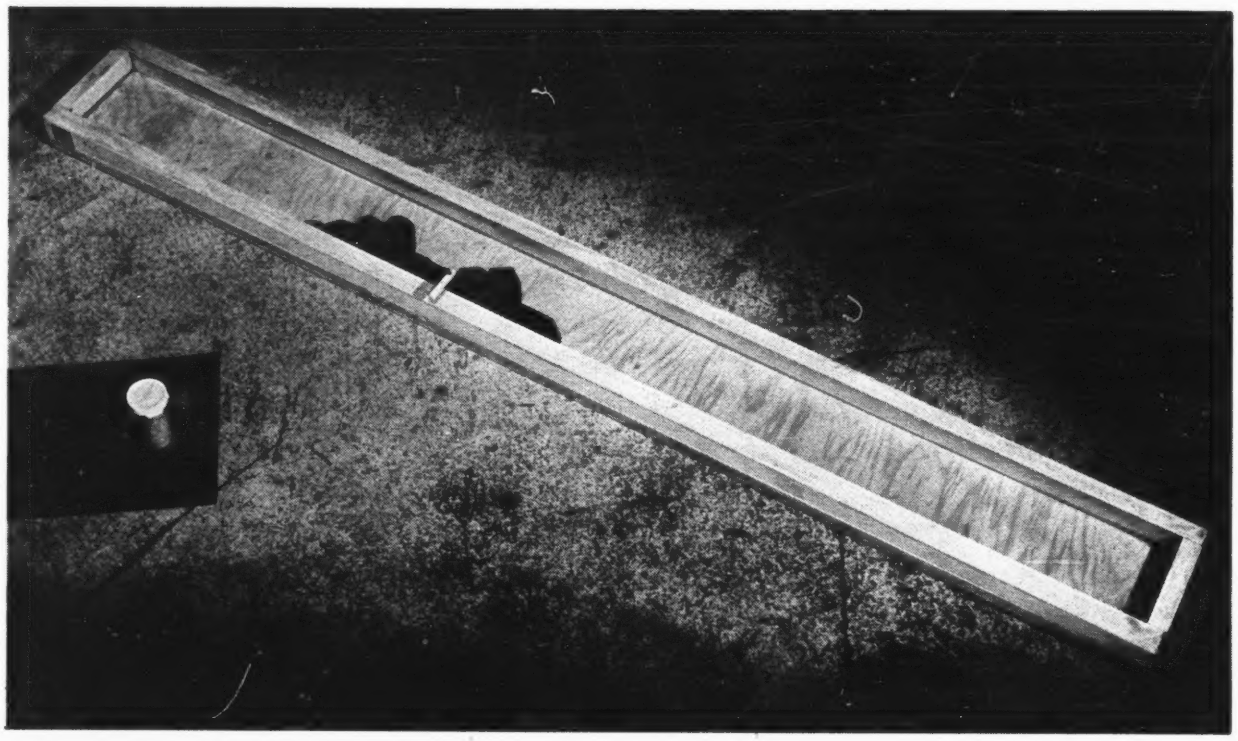


Plate 28.

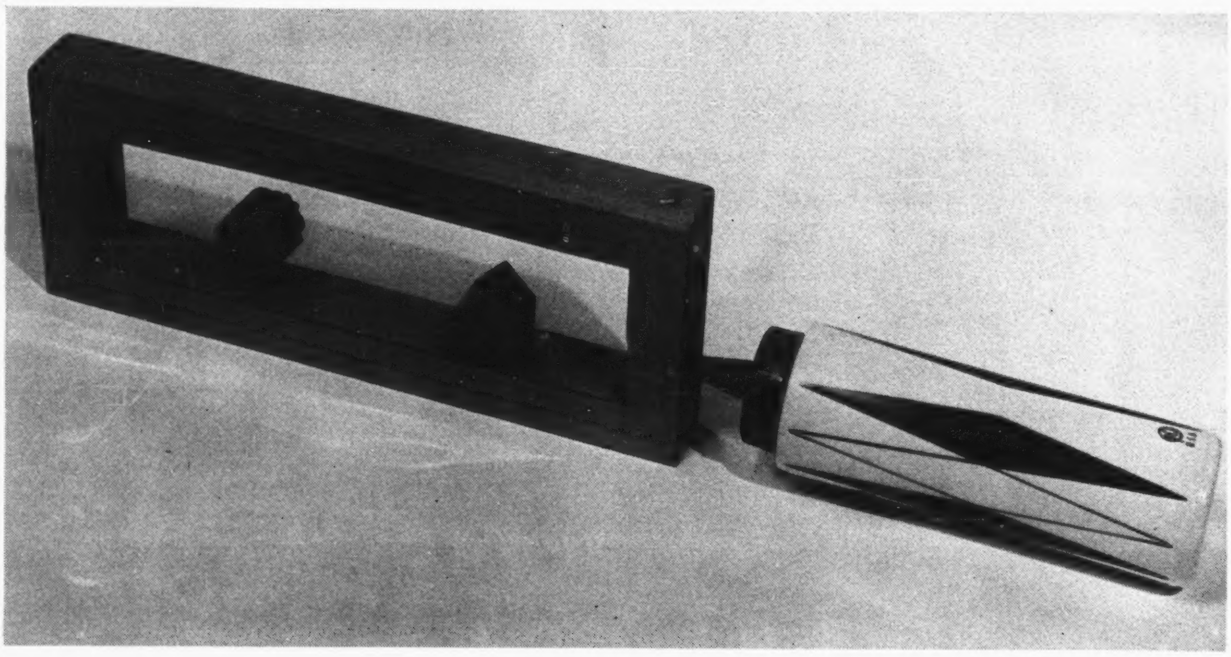


Plate 29.

In the three preciding Experiments some of the causes and effects of atmospheric stability and instability were discussed. Under unstable conditions, the developing vertical currents produce thermal turbulence (thermally produced eddy motion) that could also be seen in experiment 16. However, even in stable air turbulence develops, when the wind is strong and obstructions such as buildings, trees, hills, etc. are in its path. This turbulence is called mechanical turbulence.

a) A demonstration can be made using a fluid equivalent model, in which obstructions are moved through water. We build a trough out of wood, 30 to 36" long, 3" wide on the inside, and 1" deep (Fig. 52). This we make water proof, such as by lining it with a good grade aluminum foil or by applying suitable paint; two or three coats of resin glue can also be applied for water-proofing. This trough can also be made of sheet metal, if proper tools for such work are available. The obstructions are sawed out of wood in the shape and of the dimensions indicated in Fig. 53. If a thick enough piece of wood is not available, two thinner pieces can be sawed out together and nailed and glued on one another. The model obstructions are painted or varnished.

We then fill water into the trough not more than 1/2" deep and lay the obstruction model on its side into the water so that its base rests against one of the edges of the trough (Fig. 54). We sprinkle saw dust or cork dust or grass seeds on the water to make the water motion visible. Then we move the model along the edge of the trough very slowly from one end to the other and observe the motion of the water around it. We repeat this moving the model somewhat faster, but still slowly. 1. What is the difference in the movement of the water around the obstructions for different speeds of the model?

b) Another model using smoke to show the air motion can be similarly made. We use the same model of obstructions and place it into a cell as shown in Fig. 55. The frame of the cell is made of wood of the same thickness as the model. The front and back of the frame is covered with a sheet of transparent plastic or glass; these windows are taped or cemented to the frame. The back can also be made from cardboard or wood, but must then be painted black to make the smoke, that will be blown through the cell, visible. In the middle of one of the sides of the frame, a small hole is drilled, through which the end of a short piece of rubber hose is inserted for blowing smoke through the cell. If smoke is dispensed from a pump (Section III,D), no rubber hose is needed; the nozzle can be placed directly into the hole. Two holes are drilled through the other side of the frame, through which the smoke can escape.

Now we illuminate the cell from the side and blow a very slow stream of smoke through the box and watch it move over the obstructions. Then we repeat blowing the smoke somewhat more rapidly. 2. What is the difference between the movement of smoke around the obstructions for different speeds of the smoke?

Incidentally, we can shine a light through the cell and let the shadow fall on a screen; we then see the demonstration projected. Or we can make a similar cell on a very small scale for use in a projector for 3-1/4 x 4" slides, using two slide glasses and binding the frame and obstruction model, made of cardboard, between the glasses. A drinking straw can be used to introduce the smoke into the cell. The space between the top of the obstructions and the top of the cell should be about the same as the height of the obstruction. The slide is placed upside-down in the projector.

Material: a) Wood board (or plywood) 1/2 x 5 x 36"
Two pieces of wood (molding) 1 x 1 x 36"
Two pieces of wood 1 x 1 x 3"
Water-proof paint or a sheet of heavy aluminum foil 6x38"
One piece of wood 1 x 1-1/2 x 8"
Saw dust or cork dust, or grass seeds; nails and glue
Water

Cost: 25¢

b) Two pieces of wood 1 x 1 x 10"
Two pieces of wood 1 x 1 x 2-1/2"
Short piece of rubber hose or smoke pump.
Two sheets of glass or transparent plastic 3 x 9"
Tape or cement
Nails and glue.

Cost: 25¢

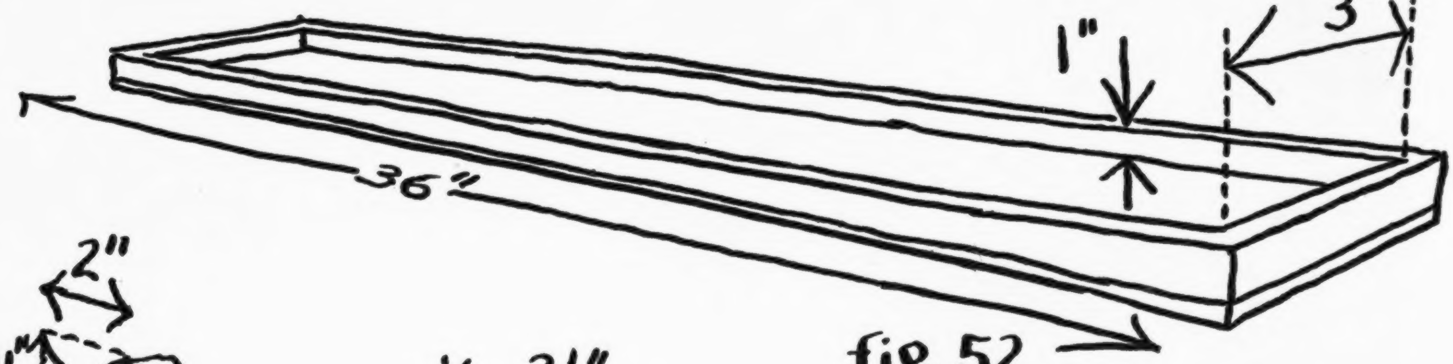


fig. 52

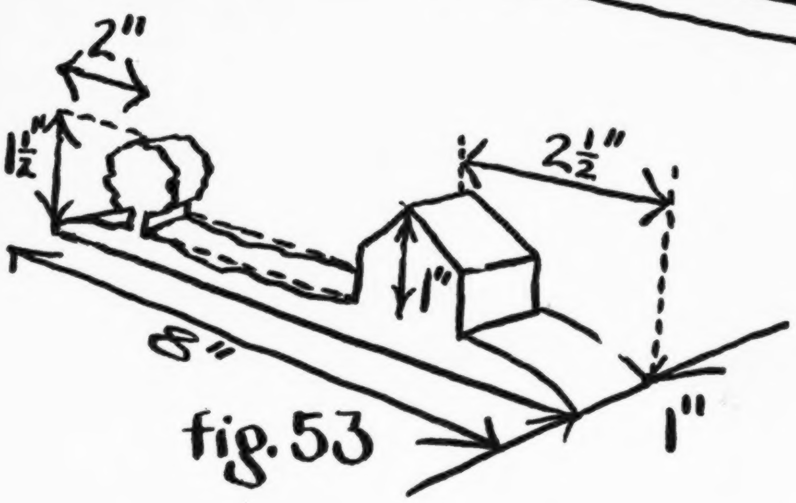


fig. 53

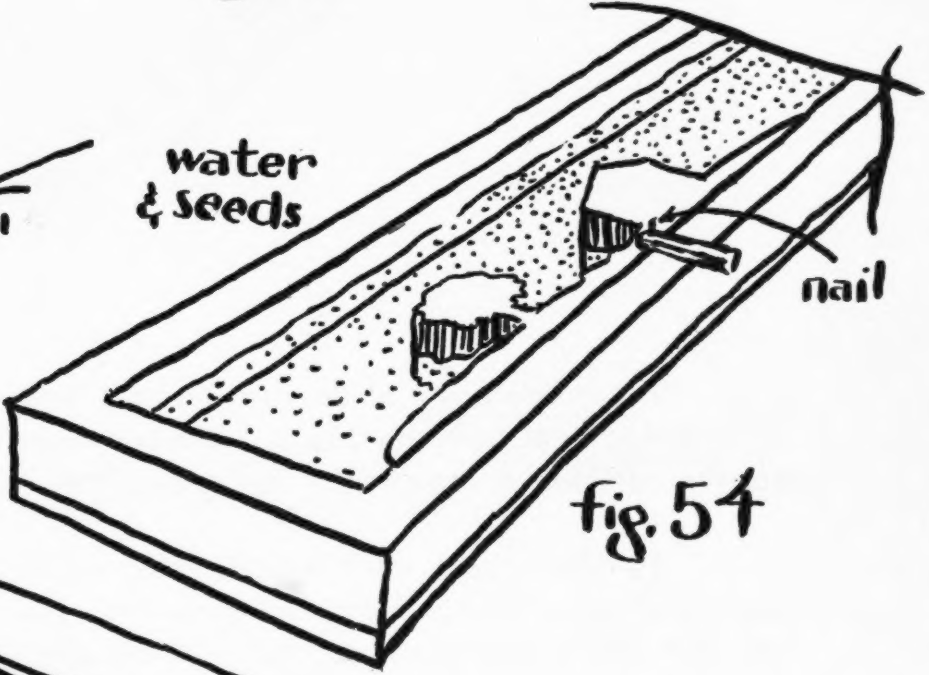

water & seeds
nail

fig. 54

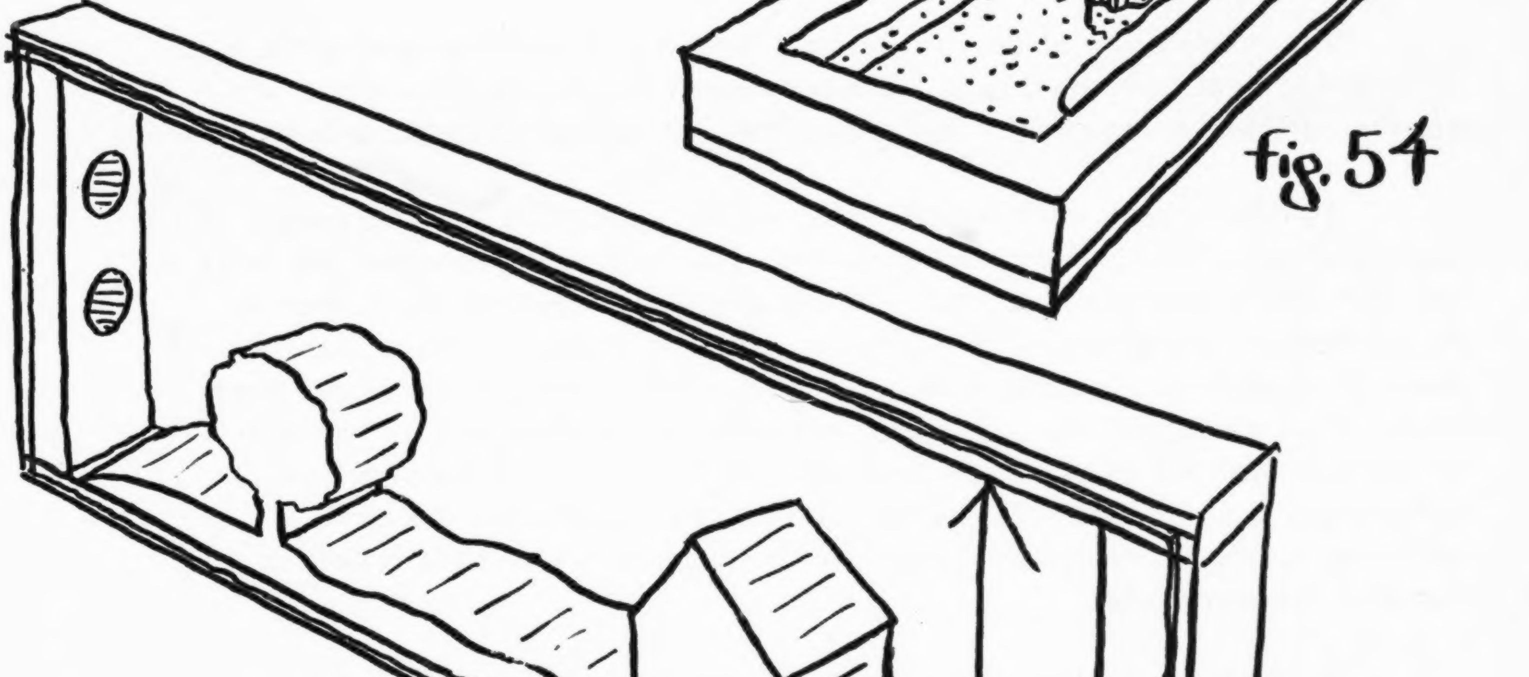

2"
smoke tube

fig. 55

25. Adiabatic Temperature Changes.

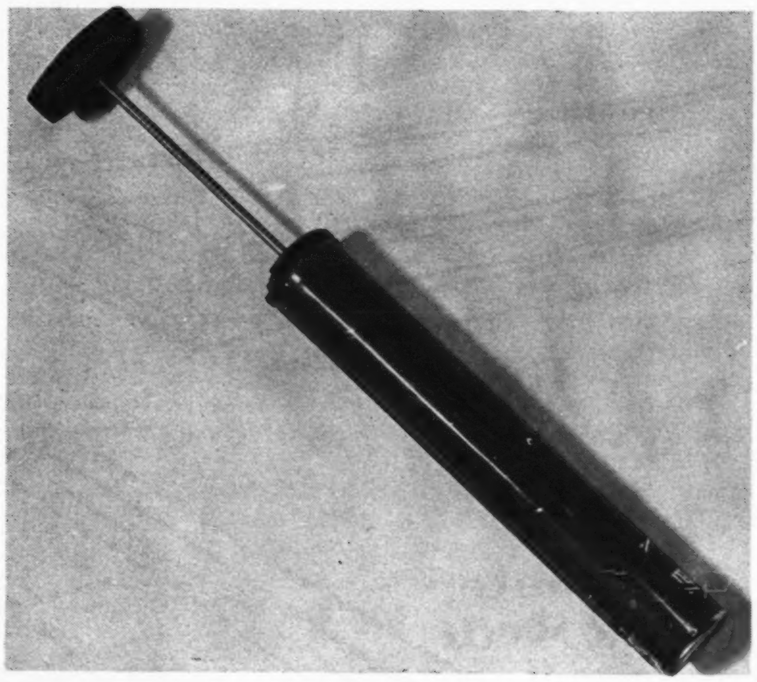


Plate 30.

The temperature of the air can be changed 1. by adding heat to the air, or removing heat from the air; 2. by increasing or decreasing its pressure without the addition or removal of heat. This latter is called adiabatic process.

To demonstrate the adiabatic process, we need a bicycle tire pump. If such is not available, we take a household insect sprayer and remove the spray can and tubing (see Plate). We hold the pump by the bottom rim so that we do not heat the pump tube with our hand. Leaving the bottom hole open, we pump 10 times in about 10 seconds and then feel the lower portion of the pump tube. Then we repeat this procedure, but put a finger airtight over the hole at the bottom of the pump. How does the tube feel now? If the piston is sufficiently tight in the tube, the heat created by compressing the air is sufficient to show a temperature rise in a thermometer whose bulb is held or taped to the pump tube.

To show the cooling of expanding air we must have an inflated automobile or bicycle tire, a football or basketball. We feel the tire or ball and notice its sensible temperature; then we let some air out and feel the temperature of the escaping air. The cooling is usually sufficient to show a temperature drop on a thermometer whose bulb is held into the escaping air stream.

Material:	One insect sprayer (30¢) or a bicycle pump One inflated bicycle or automobile tire, football or basketball One thermometer (optional)

26. Bernoulli's Principle and Pitot Effect.

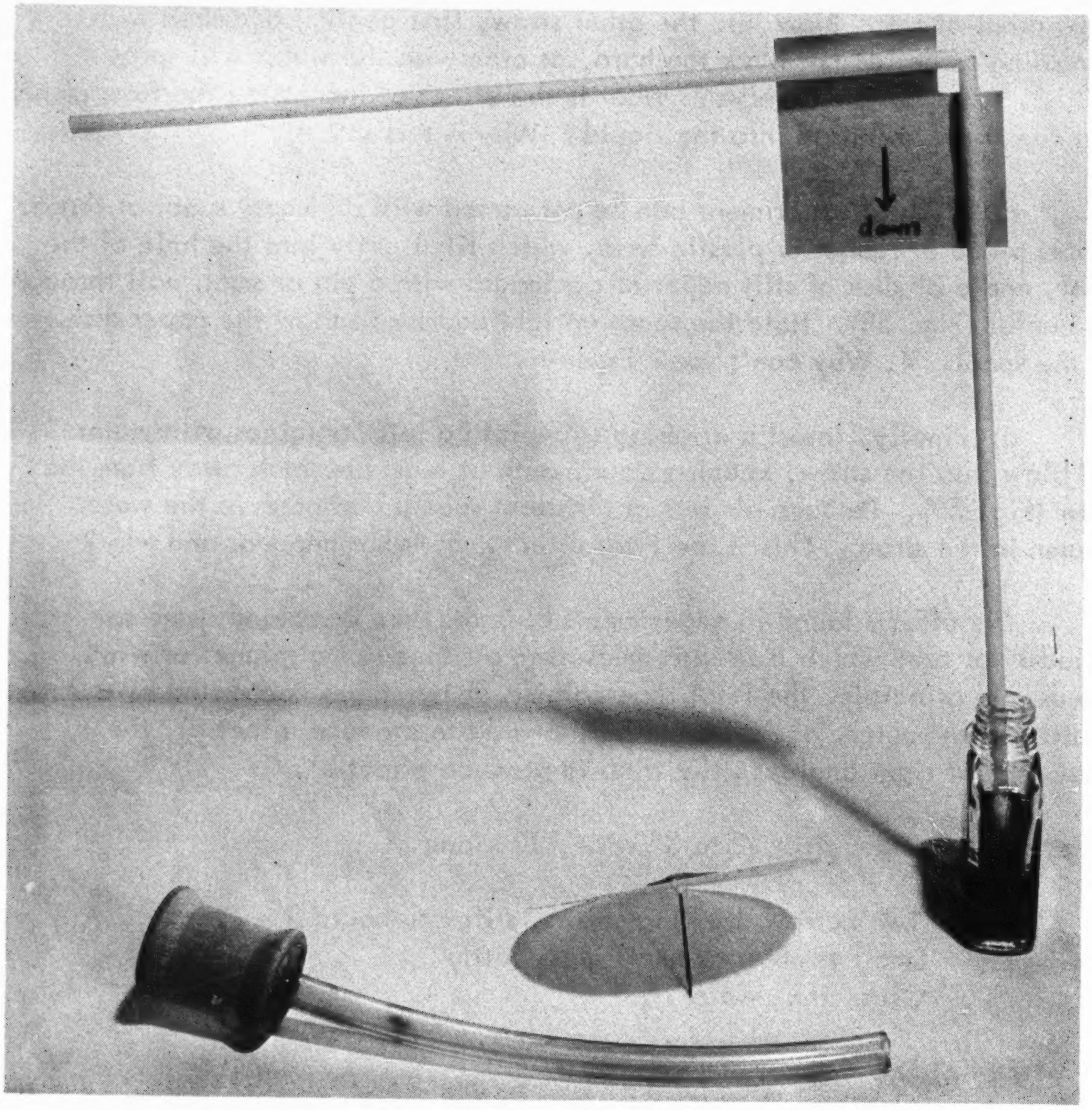


Plate 31.

According to Bernoulli's principle, when the horizontal speed of a fluid increases, the pressure decreases. This effect causes errors in barometric pressure at mountain observatories, when the wind is strong.

a) This principle can be demonstrated with a strip of notebook paper, 2 to 3" wide and 11" long. Hold one end of the strip, letting the rest hang down; then blow over the strip and observe (Fig. 56). 1. What happens and why? 2. How is this related to the principle of flight of airplanes?

b) A second demonstration involves the arrangement of an atomizer-sprayer: Glue two narrow drinking straws to a piece of cardboard, 2 x 2", as shown in Fig. 57, and put the one straw, that has the unobstructed upper end, in a small tumbler or glass bottle containing some water colored with a few drops of ink. Blow into the other straw, first gently, and then with increasing force; do not blow too hard, as otherwise the water will spray out. 3. What do you observe? What is the effect of increasing the flow of air over the straw immersed into the liquid? Why is this so?

c) A third experiment can be performed with an empty spool of thread, a short piece of rubber or plastic hose, which fits tightly into the hole of the spool, and a 3" disk of stiff paper or cardboard with a pin or small nail through the center (Fig. 58). Hold the spool upright and try to blow the paper disk off the spool. 4. Why can't you? Explain.

d) Finally, insert a drinking straw into a tall container with water and blow into the straw, keeping your mouth at least one inch away from the straw (Fig. 59). Produce air jets of different speeds and observe the water column in the straw. This is the Pitot effect. 5. What happens and why?

The effects found in experiments b) and d) are combined in the so-called Pitot tube which is used in measuring air speed of airplanes or wind speeds. In principle, the Pitot tube consists of two tubes connected by a sensitive manometer, one tube facing the wind to produce effect d), the other tube at right angles to the wind to produce effect b).

Material: a) Paper strip, 2 to 3" wide, 11" long.

b) Two narrow drinking straws, stiff cardboard 2 x 2"
Small tumbler or small glass bottle
Glue, ink, water.

c) Empty spool of thread
6" piece of rubber or plastic tubing to fit into spool-hole
3" disk of stiff paper or cardboard
One pin

d) Drinking straw
Tall tumbler or jar with water.

Cost: 10¢

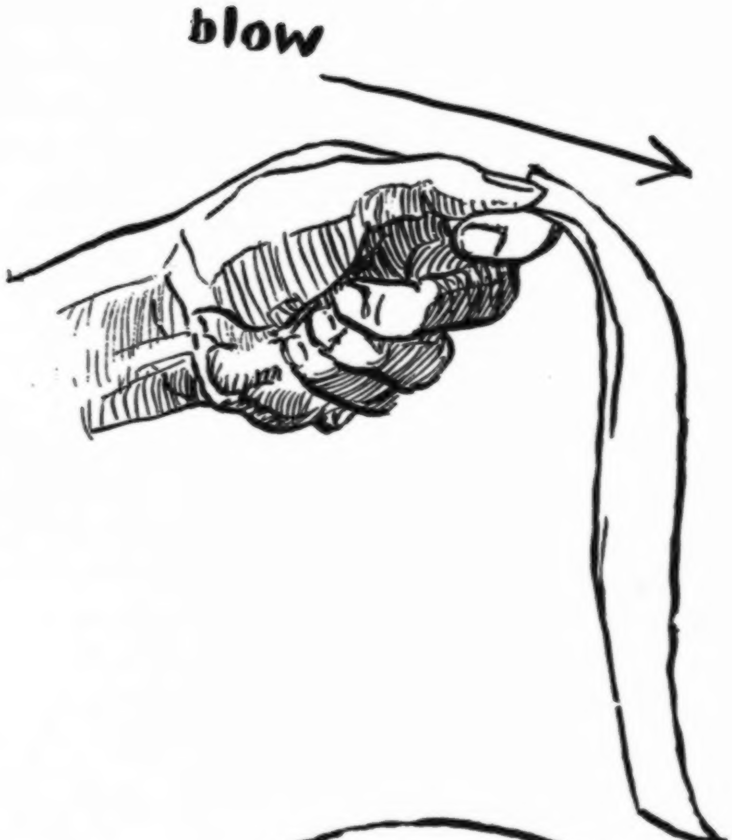


fig. 56

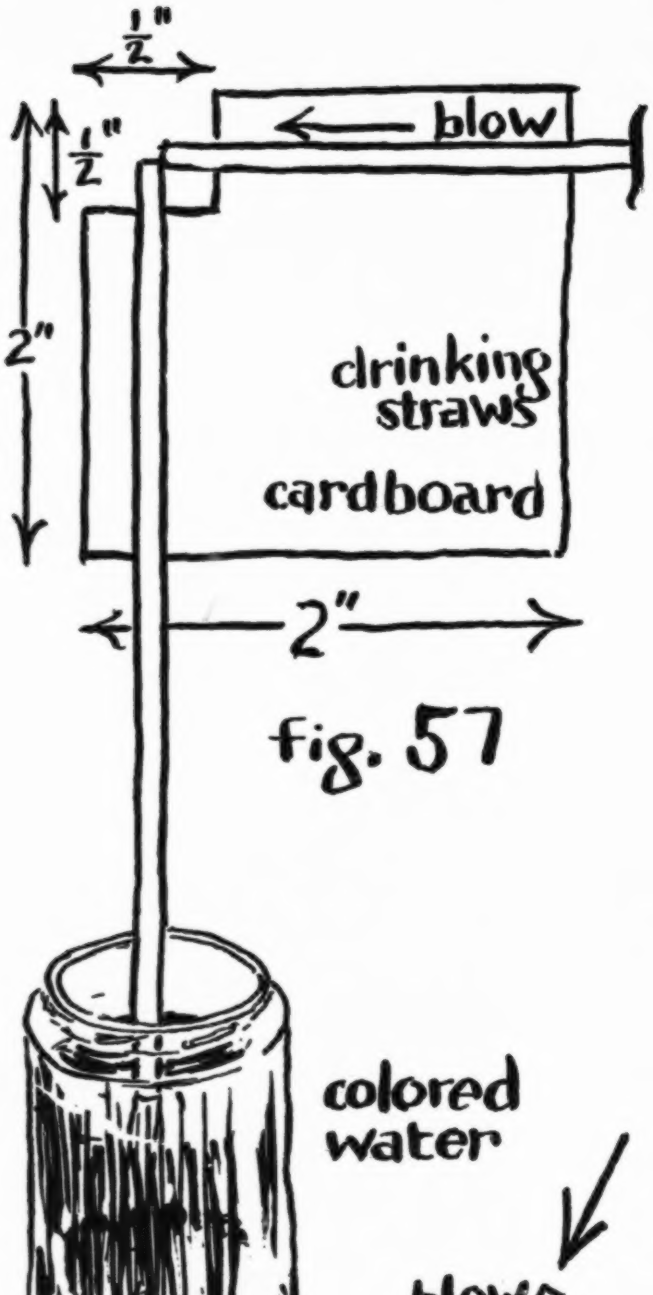

1/2"
1/2"
blow
2"
drinking straws
cardboard
2"
colored water

fig. 57

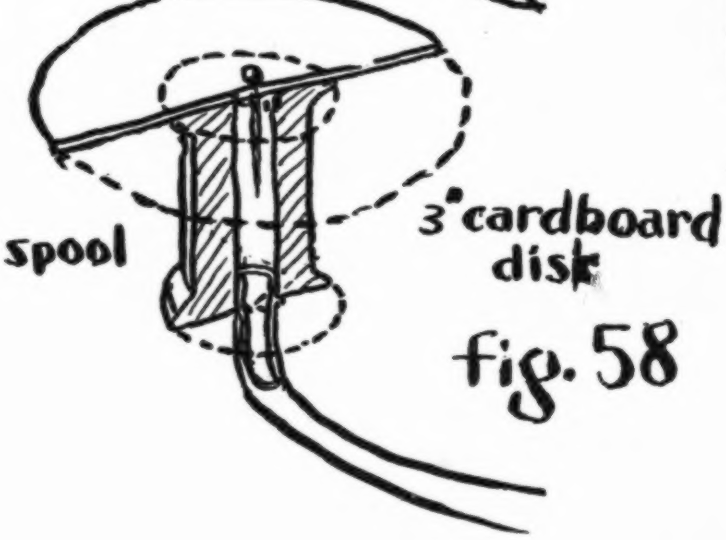

spool
3" cardboard disk

fig. 58

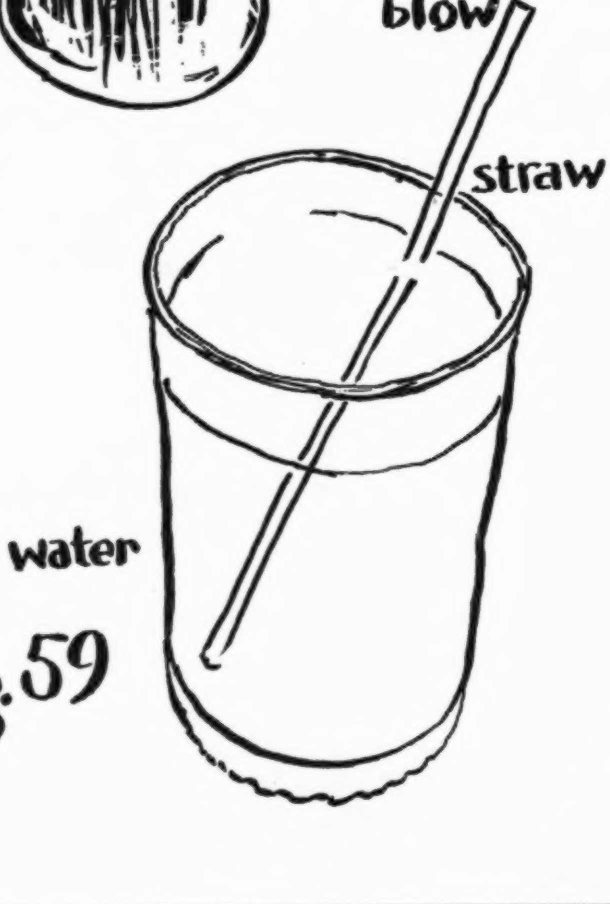

blow
straw
water

fig. 59

27. Coriolis Effect.

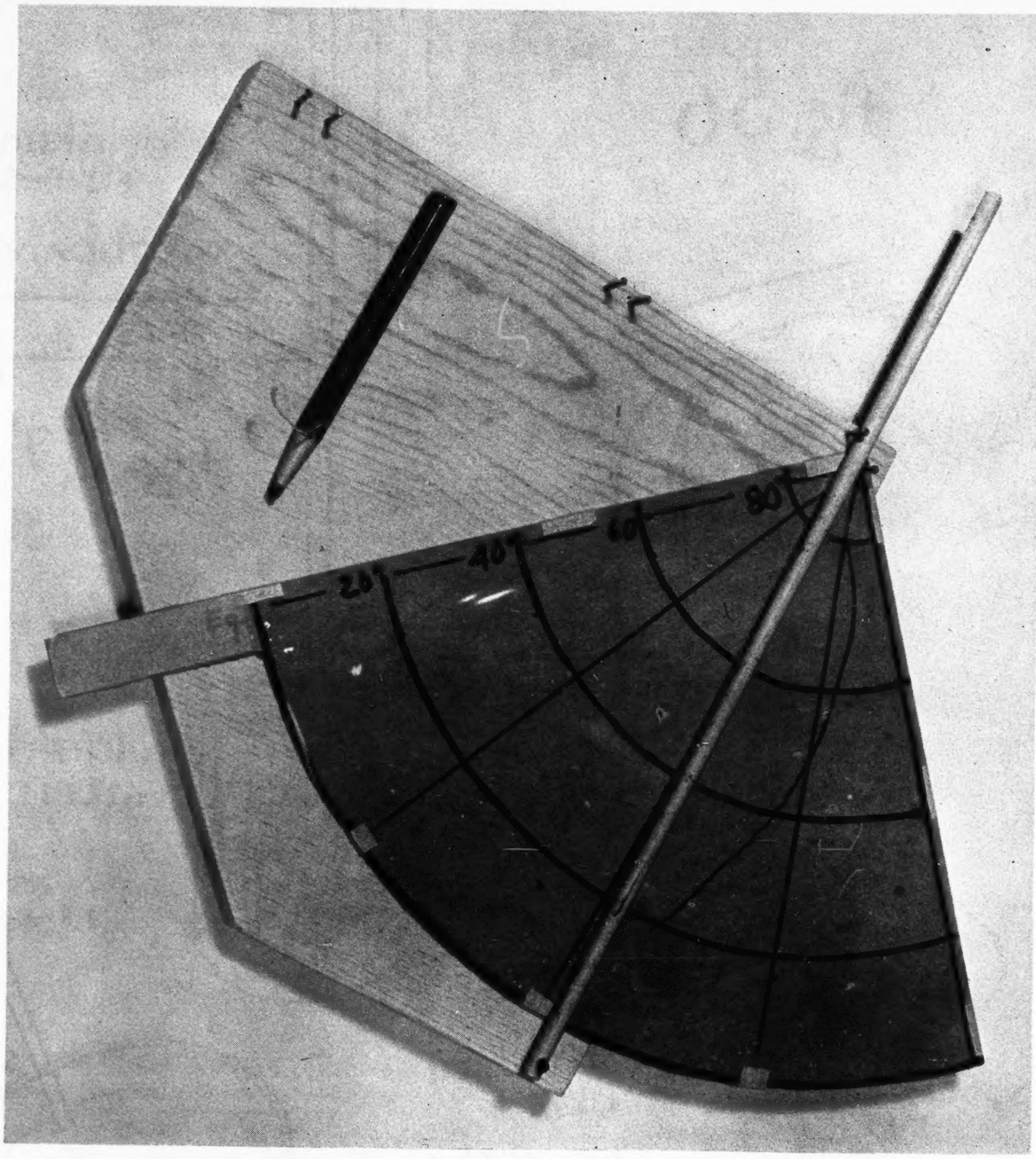


Plate 32.

In a rotating system, such as the earth, there is an apparent force, called Coriolis force according to its discoverer, which deflects, relative to the system, a moving body from its straight path, although an observer outside the system would see the body move in a straight path according to Newton's first law of motion.

The earth rotates around its axis from west to east. When viewed from the north pole, the rotation is counterclockwise, whereas when viewed from above the south pole, the rotation is clockwise. Because of the different sense of rotation of the two hemispheres, the direction of deflection of moving bodies on the northern hemisphere is opposite to that on the southern hemisphere. At the equator there is no deflection; at the poles the deflection is greatest. In meteorology, the Coriolis deflection is very important, because it modifies the path of moving masses of air, as observed on the earth's surface.

For making a demonstration model, cut off one corner a square piece of wooden board (or plywood) 10 x 10", by sawing from the middle of one side to the middle of an adjacent side (Fig. 60). Drill (or burn with a hot nail) a small hole near the end of a straight stick of wood 13" long, 1/4" or 3/8" diameter, such as a dowel rod or molding. Fasten this stick, which will be used as a straight-edge, with a loosely fitting nail, brad, or pin to the lower right corner of the board, as shown in Fig. 60, so that the stick can be moved over the board. Place the stick parallel to the right-hand edge of the board and hammer lightly a small nail on the right side of the stick and 1/2" down from the top edge of the board. This point will be the pole of the earth. With the stick against the nail, hammer another nail or brad firmly to the left side of the stick and 1/4" down from the top edge of the board, letting about 1/2" of the nail stick out of the board. Clip the nail head off. Now lift the stick out from between these two pins and place it in the middle of the top edge. Hammer two brads or nails, one on each side of the stick and 1/4" down from the top edge. Clip off the nail heads, lift the stick out from between the nails, and place the stick at the left end of the top edge. Again put two brads on each side of the stick as before. Now we cut a piece of stiff cardboard 8-1/2 x 11" (e.g. the backing from a note-paper pad) as shown in Plate 32. This represents a plane view of a quarter hemisphere, the pole being at the center of the arc, about 1/4" from the corner of the cardboard. We can draw several circular arcs around the pole to represent the various latitudes, and several radii to represent longitudes. We then fasten this earth quadrant with a nail through the respective poles on the cardboard and the wooden board.

If this model is to be used repeatedly, a sheet of cellophane, other clear plastic, or very thin onionskin or tracing paper is fitted over the quadrant and taped to it at several places along the edges.

Place the straight-edge stick in the pin slot at the pole while the quadrant handle is resting against the two pins on the upper left. Now move a soft pencil (if quadrant is covered with cellophane or plastic, use grease pencil or eye-brow pencil) up from the equator toward the pole along the left side of the straight edge, at the same time moving the quadrant handle from the upper left to the lower right corner of the board. Move both pencil and quadrant as evenly as possible. The curvature of the pencil line on the quadrant shows the deflection on the northern hemisphere, because the quadrant was moved counterclockwise. If you start with the handle at the bottom and move it toward the upper left, the curvature of the pencil line on the quadrant shows the deflection on the southern hemisphere. Note, that in this model, the amount of curvature does not represent the amount of deflection; only the direction of curvature (looking in the direction in which the pencil moves) shows the direction of deflection.

Repeat the experiment by moving the pencil from the pole toward the equator. To see the direction of curvature, you must now look from the pole down the pencil line.

Then place the straight edge in the next slot and repeat, etc. When imitating the conditions on the southern hemisphere, place the pencil on the right side of the straight edge, so that the quadrant will not drag the pencil along.

1. What is the deflection on the northern hemisphere? 2. What is the deflection on the southern hemisphere? 3. Does the direction of the pencil movement up or down the straight edge make any difference regarding the direction of deflection? 4. Does the position of the straight edge in the various slots make any difference?

Note: The model can be made in any desired size; also, if no wood is available, it can be made entirely of cardboard. In this case, push short nails with large heads through the cardboard from the bottom and put scotch tape over the heads to hold them in place. The straight-edge is made by pasting two or three strips of cardboard, each 13" long and 1/4" wide on top of one another. Instead of a hemisphere quadrant, one can also make a polar projection of an entire hemisphere on a circular disk; the pole is placed in the center of a square board, and the straight edge is pivoted at the middle of the bottom edge of the board. The pin slots for holding the straight edge are placed as shown in Fig. 61.

Materials:	One wooden board 10 x 10", 1/2" thick, or more One piece of stiff cardboard 8-1/2 x 11" Seven nails or brads One stick of wood 13" long, 1/4" diameter (dowel rod)
Cost:	15¢

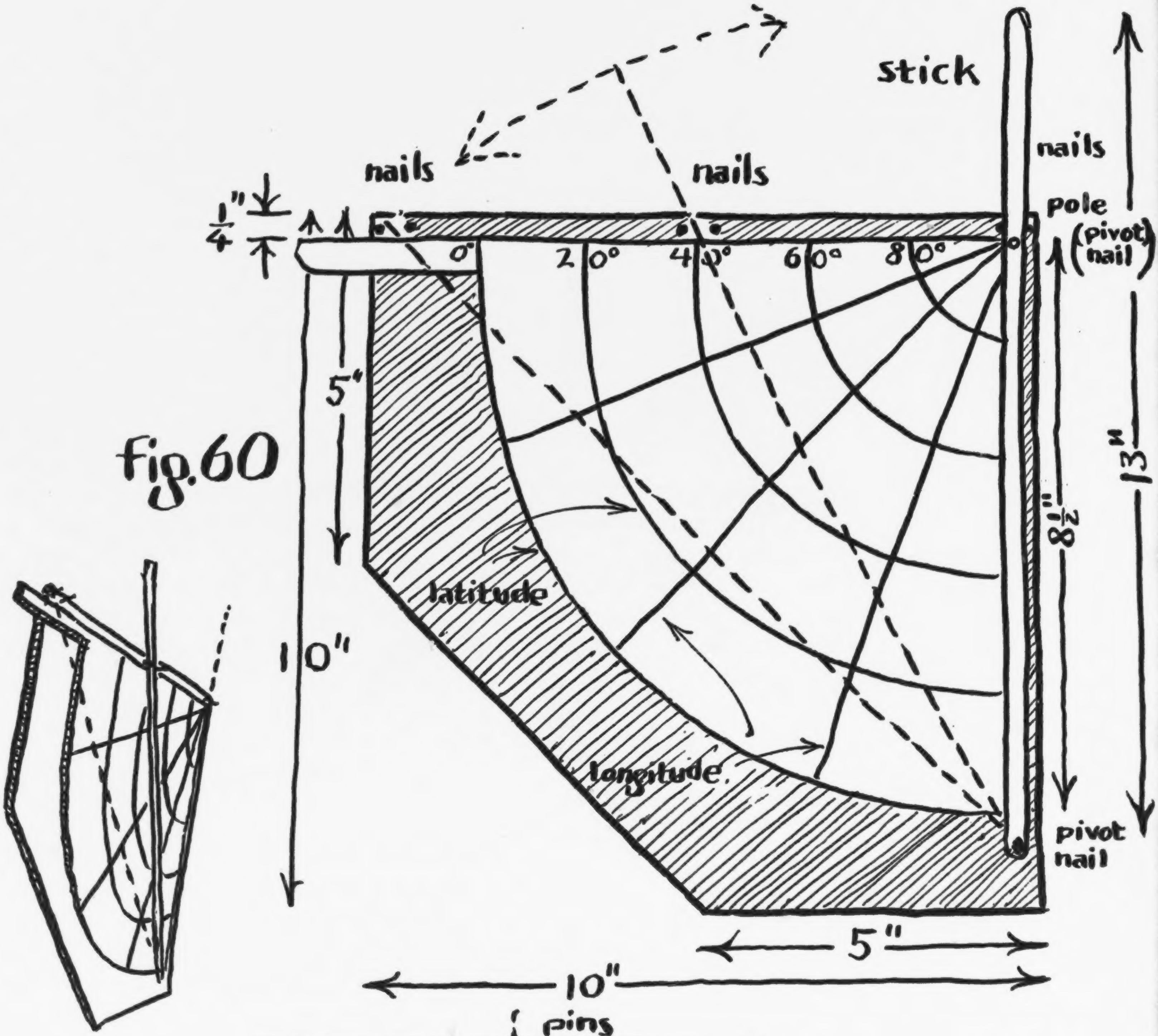

stick
nails
nails
nails
1/4"
pole
(pivot nail)
0°
20°
40°
60°
80°
5"
10"
latitude
longitude
8½"
13"
pivot nail
5"
10"

fig.60

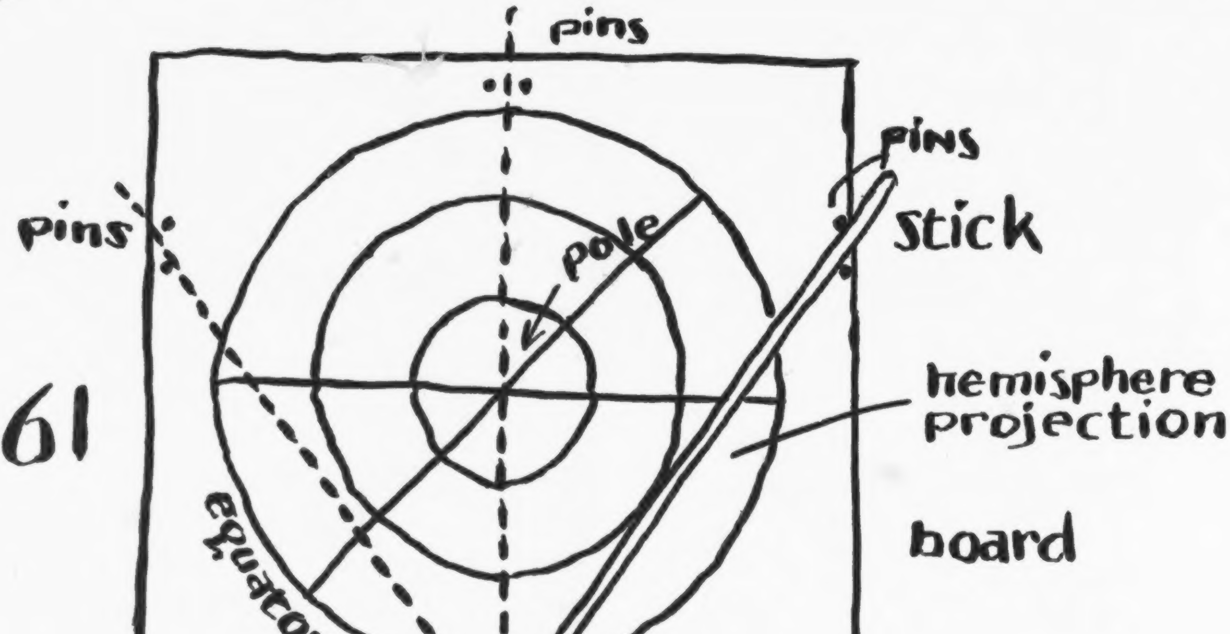

pins
pins
pins
stick
pole
hemisphere projection
board
equator
pivot of stick

fig.61

28. Circulation around Highs and Lows.

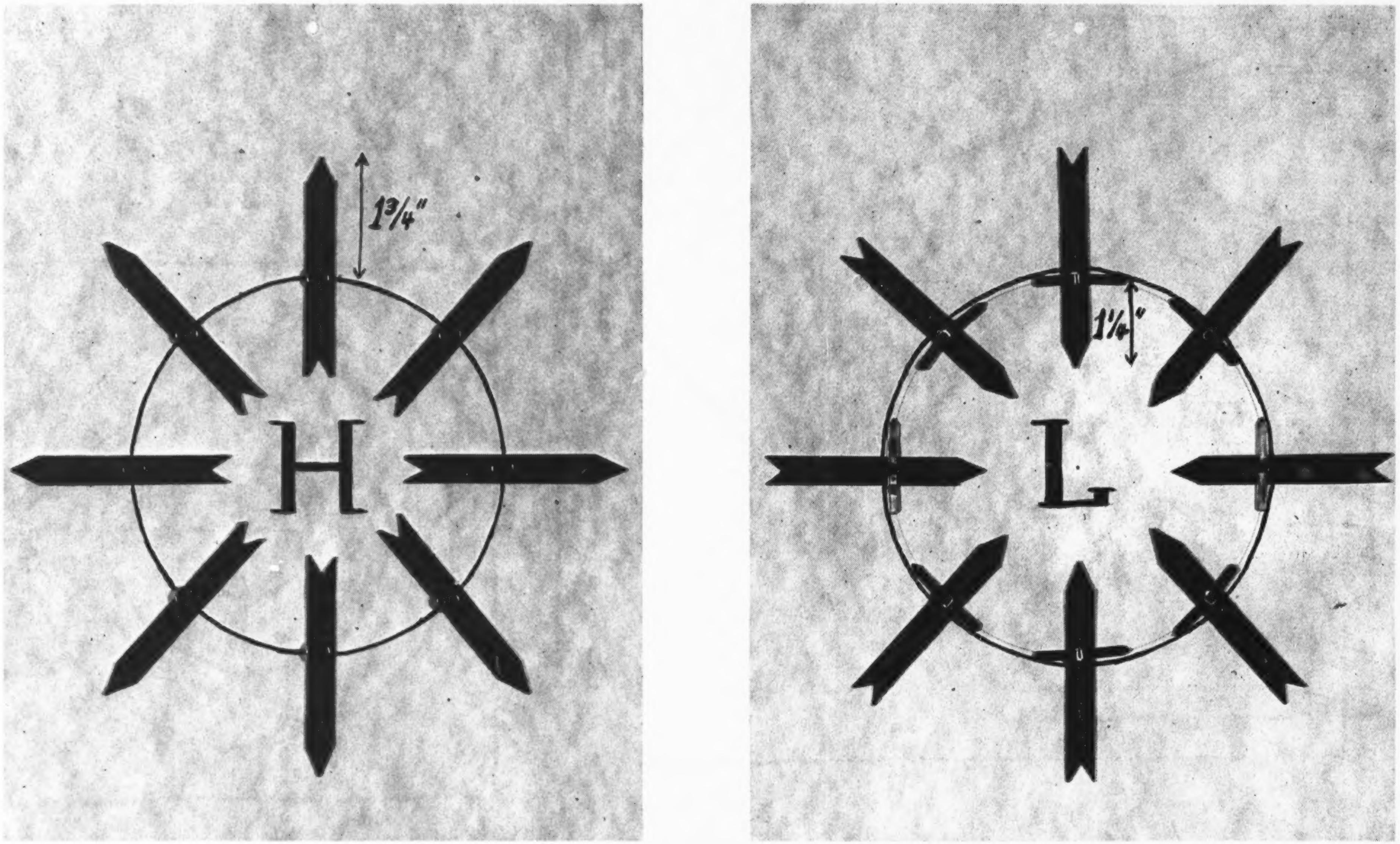


Plate 33.

Air moves from areas of high pressure to areas of low pressure (see Experiment 3). Due to the Coriolis effect (Experiment 27) the air does not flow straight out of a high pressure area or straight into a low pressure area, but tends to circle around these areas. The Coriolis effect, together with friction between the air and the ground, causes a spiral flow of air out of a HIGH or into a LOW. This can be demonstrated with a simple model.

We draw a circle of 5" diameter on both sides of a stiff piece of cardboard, 8-1/2 x 11"; the center of the two circles should coincide. In the center of one circle we mark a large "H" to represent a schematic high pressure area; in the other circle we mark a large "L" to represent a a low pressure area. Then we cut 16 arrows, 3/8" wide and 3" long, out of black cardboard; in eight of these arrows we punch a small hole 1-3/4" from the arrow tip; these are the wind arrows for the HIGH. In the other eight we punch a hole 1-1/4" from the tip; these are the arrows for the LOW (Plate 33). Now we punch eight holes around the circles, one each in the north, northeast, east, etc. position. With eight paper fasteners we fasten the two sets of arrows on the respective sides of the board and tap the fasteners lightly with a hammer, so that the arrows stay in position. On the HIGH, the arrows are set so that they point straight out across the circle, on the LOW they should point straight toward the center of the circle. This would be the air flow due to the pressure gradient force in the absence of the Coriolis effect.

On the northern hemisphere, the Coriolis deflection is to the right; so we turn each arrow about 30° to 45° to the right, i.e. clockwise. (In the absence of friction, the Coriolis force would turn the flow 90° from the direction of the pressure gradient force.) 1. Is the resulting circulation a clockwise or counterclockwise spiral for the HIGH? For the LOW?

To show the circulation patterns for the southern hemisphere, we return the arrows to their initial position and then turn each about 30° to 45° to the left (counterclockwise). 2. What are the resulting circulations for the HIGH and the LOW?

The Buys Ballot rule (pronounced: boys-ballot) states that, on the northern hemisphere, if a person stands with his back to the wind, low pressure lies to the left and slightly forward; high pressure lies in the opposite direction. 3. What is the Buys Ballot rule for the southern hemisphere? 4. In which direction is the LOW relative to an observer who notes a south wind a) on the northern hemisphere, b) on the southern hemisphere?

Material:	One sheet of cardboard, 8-1/2 x 11" or larger Sixteen strips of black cardboard, 3/8 x 3" each Eight small paper fasteners
Cost:	10¢

29. Tornado Model.

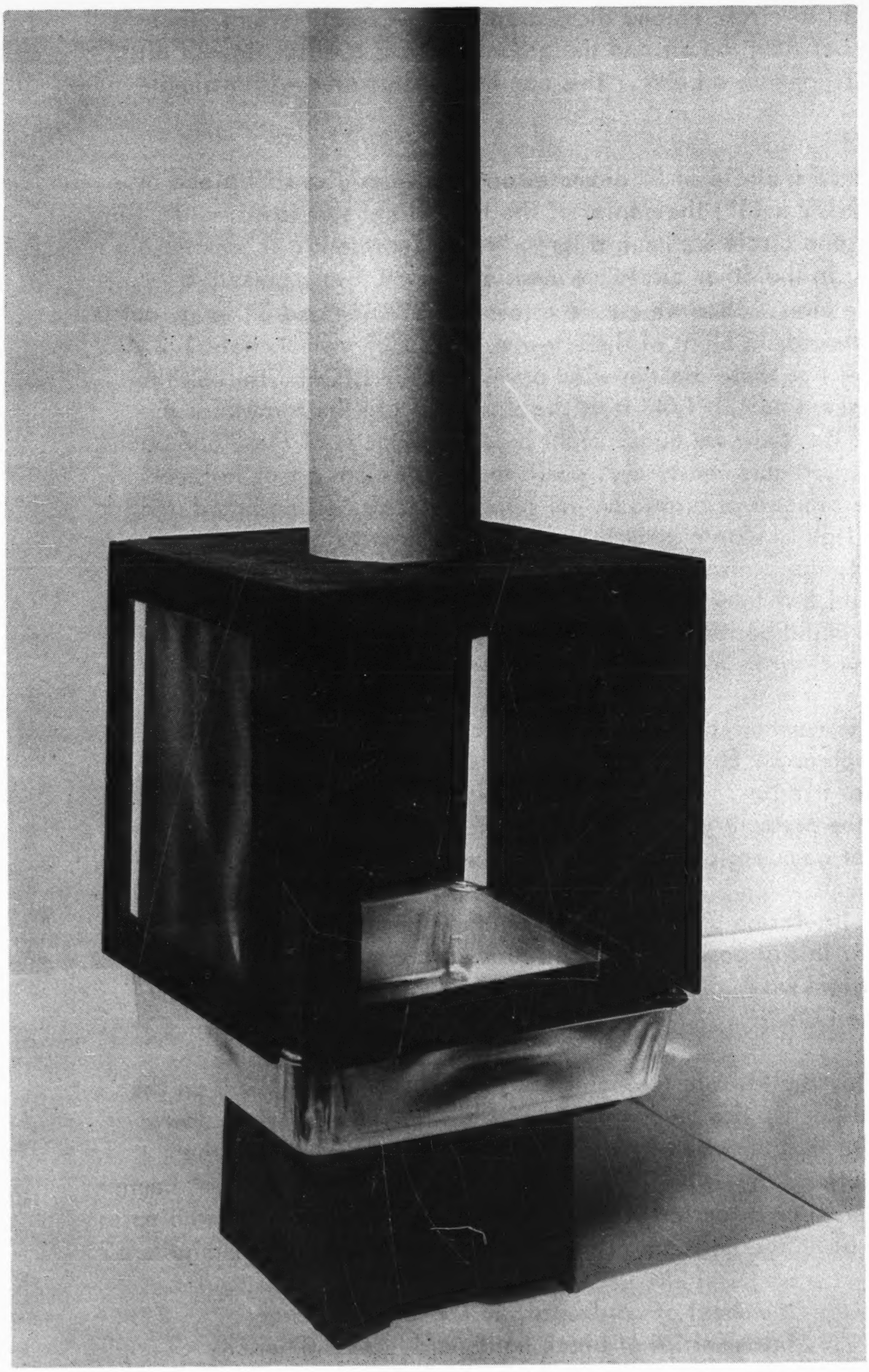


Plate 34.

Tornadoes (Twisters) are the most violent and destructive storms. These whirlwinds have a diameter that rarely exceeds 1/4 mile, but the wind speeds are of the order of several hundred miles per hour. More tornadoes occur in the U.S.A. than in all other countries combined.

Great instability of the lower atmospheric layers is one of the prerequisites of the formation of tornadoes. By imitating natural conditions we can make a working model of a miniature tornado. For this we must provide the following: 1. A system of air that is very unstable, i.e., one in which the air is very warm at the bottom and relatively cold at the top (see Experiments 21, 22 and 23). This is achieved by heating the air from below; the resulting convection is increased by having the heated air rise through a chimney. 2. A means of imposing a rotating motion on the rising air; this is done by guiding the cold air entering the system to force the hot, and therefore less dense air up the chimney. 3. A source of steam to make the whirl visible as the cloud-funnel does in nature.

The model consists of a square pan (in which water is heated) and a cubic box (without a bottom) on top of it. Two adjacent sides of the box have windows, one through which light shines, the other for observing. On the right-hand side of each of the four box sides are slots from top to bottom; the width of the slots is about 1/16 of the side length of the box. The top of the box is as large as the top of the pan and has in the center a hole, the diameter of which is 1/3 of the side length. Over this hole a chimney 2-1/2 to 3 feet long is placed, having a diameter slightly larger than that of the hole.

The model described here is built around a square baking pan 8" x 8" and 2" deep. The box is made of masonite, but sheet metal, thin plywood, or heavy, shellacked cardboard can also be used. Needed are the five sheets shown with their dimensions in Figure 62. To attach the sides to the top, glue, nail, or screw four strips of wood or molding of about 3/4 x 3/4 x 6" to the underside of the top sheet as shown at the bottom of Figure 62. Now paint the surfaces that will be the inside of the box with flat black paint. When dry, the sides are fastened (with glue, nails, or screws) to the top so that the two windows are next to each other and that there is a 1/2" slot on the right-hand side of each of the four sides as shown in Plate 34. About 3/8" above the bottom edge of each side, punch or drill a small hole about 1" from the left end and another hole about 3/8" from the right end. Cut four pieces of stiff wire, each 2-1/2" long, and pull through the holes across each corner as shown in Figure 63. Set the box on the pan so that the rim of the pan is inside the box and the wires rest on the pan corners. Press the wire ends tightly against the box sides and pull them while bending, so that the box sits fast on the pan. Then glue or cement sheets of transparent plastic or thin glass, each about

6 x 6-1/2", over the cut-out area of the window frames.

The chimney should be 30" to 36" long and 3" diameter. It can be made from sheet metal, stove pipe, or mailing tubes. Stiff wrapping paper rolled into a tube in several layers can also be used; however, since the chimney will be exposed to steam, the inside of the paper should be shellacked. For greater stiffness three tin cans of 3" diameter, from which tops and bottoms have been removed, can be glued to one edge of the paper (see Fig. 64). The paper is then rolled over the tin cans and glued. The chimney is fastened to the box top with glue, scotch tape or masquing tape. Make sure that there are no air leaks between chimney and box, between sides and top of the box, and between the box and the pan, so that the air can enter the box only through the slots.

Now fill the pan through a slot with hot water to within 1/2" from the rim and place the model on a hot plate, sternoburner, or other heat source. A small electric immersion heater can also be used. The water should be heated until ample steam develops, but it should not boil. Have a bright light shine through one of the windows and observe through the other. We can make the steam better visible by blowing smoke into the box.

1. What do you observe? 2. What are the directions of the motions? 3. Why does smoke make the steam better visible? 4. What difference would it make, if all the slots were on the left side instead of the right side? 5. What motion do you observe on the water surface? Why? (The motion of the water can be made better visible by blowing a small amount of fine ashes or chalk dust onto the water) 6. What is the function of the hot water?

Materials:
Four sheets of masonite 7-1/2" x 8"
One sheet of masonite 8" x 8"
One baking pan 8" x 8" x 2"
Two sheets of clear plastic 6" x 6-1/2"
One sheet of wrapping paper about 30" x 36" (can be pieced together from smaller sheets)
Three tin cans, 3" diameter
Four pieces of stiff wire, each 2-1/2" long (paper clips)
Four strips of wood (molding) about 3/4" x 3/4" x 6"
Flat-black paint
Glue (waterproof); short nails or screws; masquing tape, adhesive tape, or scotch tape
A light source and a heat source

Cost: less than $2.00

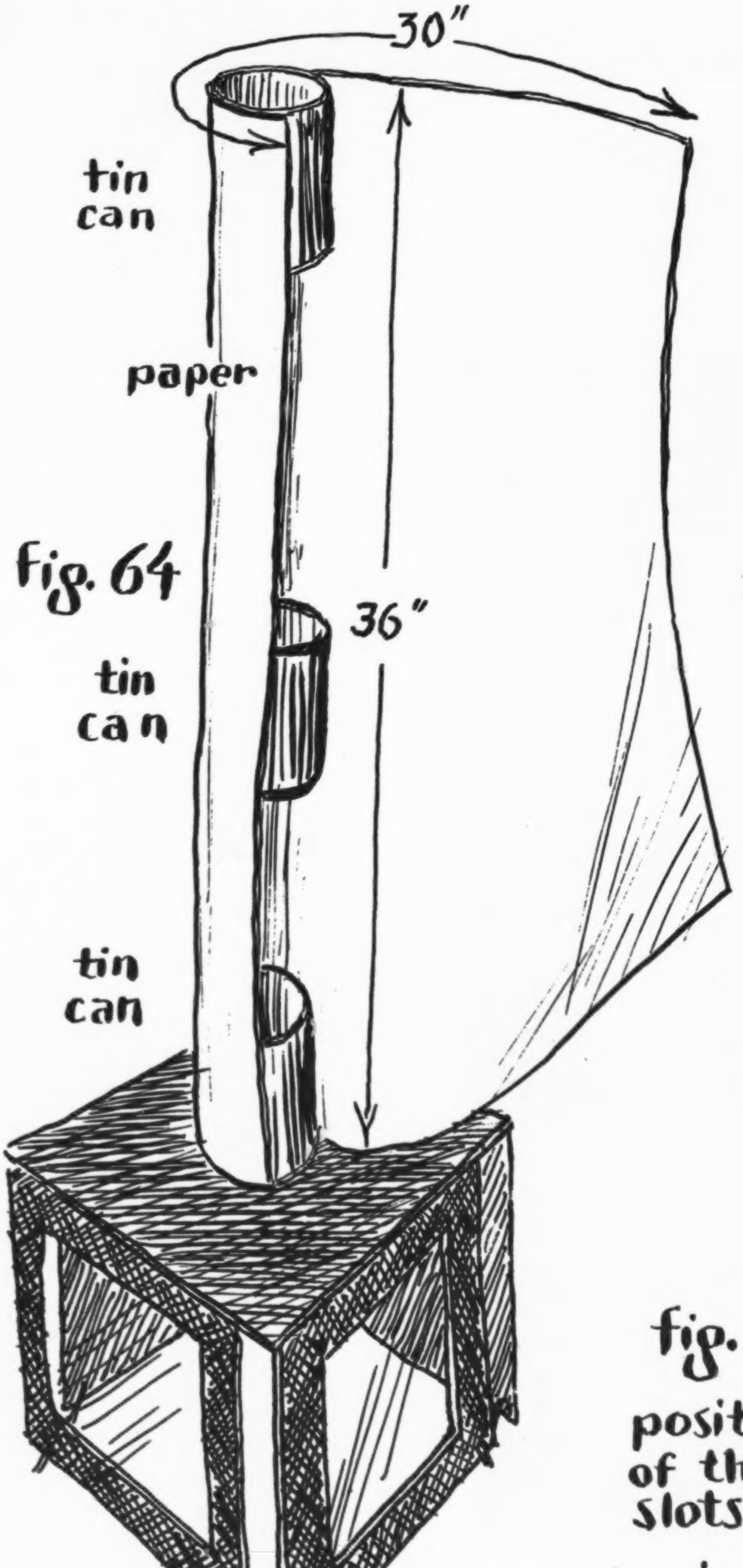
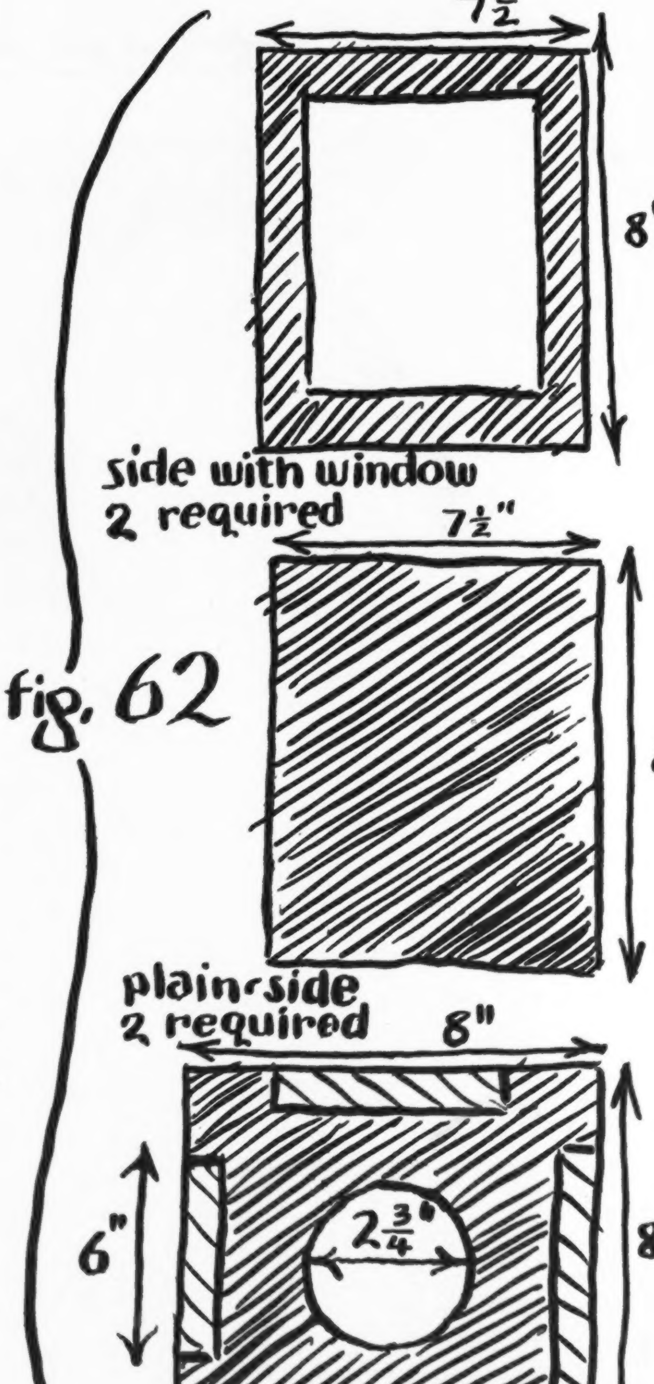

30"
tin can
paper
36"
tin can
tin can

fig. 64


7½"
8"
7½"
8"
8"
6"
2¾"
8"

side with window
2 required

plain side
2 required

the top from underneath

fig. 62

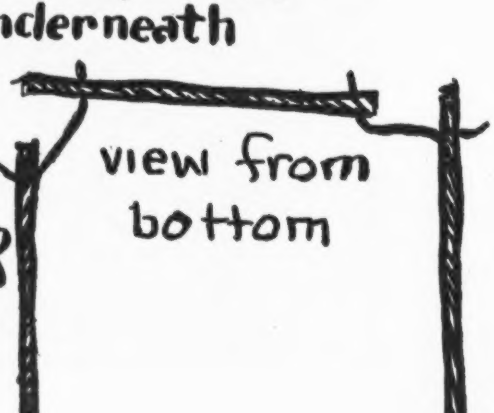

view from
bottom

fig. 63

positioning
of the
slots

note wires

30. Effects of Temperature and Pressure Changes on Cape-Cod Type Barometer.

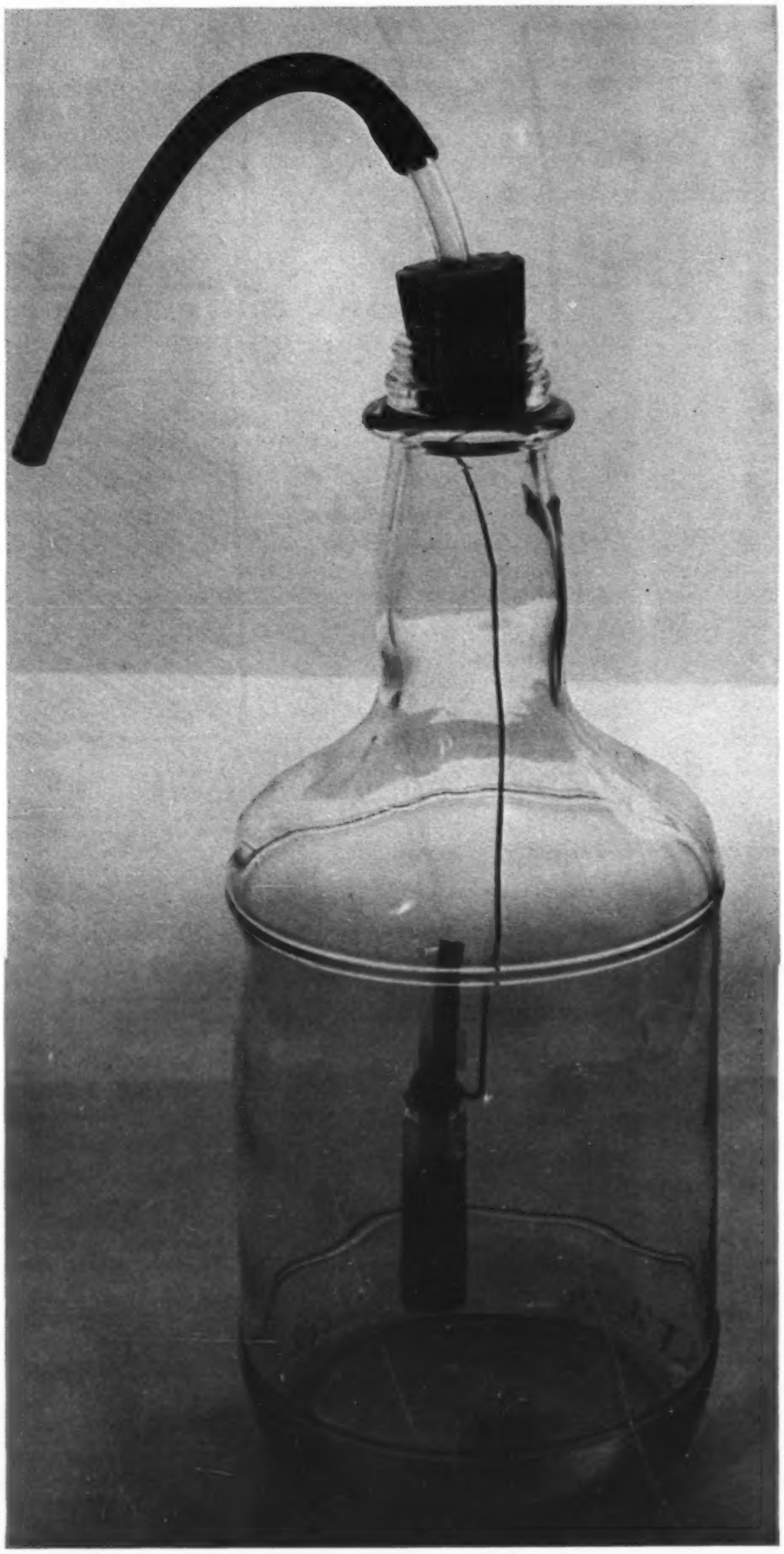


Plate 35.

Cape-Cod barometers come in a great variety of shapes: flasks with curved necks, swans, etc. (Fig. 65). All are based on the same principle: A volume of air is separated from the air in the environment by a liquid; as the pressure on the outside increases, the volume of air inside the barometer is compressed, and the level of the liquid falls. When the pressure falls, the air inside the barometer expands and pushes the liquid up. It is easily demonstrated that such a primitive barometer responds also to changes in temperature.

We make a small Cape-Cod barometer using a small pill tube of glass or plastic, about 2-1/2" long and 3/4" diameter, and an eye dropper. The neck of the tube should be just a little smaller than the widest part of the rubber bulb of the eye dropper. We take the bulb off the eye dropper and put it loosely upside down into the neck of the tube as shown in Fig. 66. Then we cut the bulb 1/4" below the top of the tube and 1/8" above the top of the tube. Then we insert the dropper tube, tip down through the rubber ring, which we cut out of the bulb, so that the dropper sticks more than half-way down the pill tube. Some water, dyed with red or blue ink, is put into the barometer so that the water fills the pill tube to the middle, above the tip of the dropper, and about half the length of the dropper above the pill-tube rim, as shown in Fig. 67.

We can make a scale on a strip of white paper and tape to the portion of the dropper tube that sticks out of the pill tube.

We tie a piece of string or wire around the barometer and lower it into a bottle with not too wide a neck. It is best to use the gallon jug that was made into a fog bottle in experiment 18 . Observe what happens to the water level in the barometer when we suck air out of the bottle and when we blow air into the bottle. Now retrieve the barometer from the bottle and immerse it to the neck of the pill tube first into cold water, then into hot water. 1. How does the barometer respond to temperature changes? 2. To what kind of pressure change does a temperature rise correspond? a temperature fall?

Material:	One eye dropper One small pill tube, about 2-1/2" long, 3/4" diameter One gallon or half gallon jug (from experiment No. 18) One foot of thread or wire Hot and cold water
Cost:	15¢

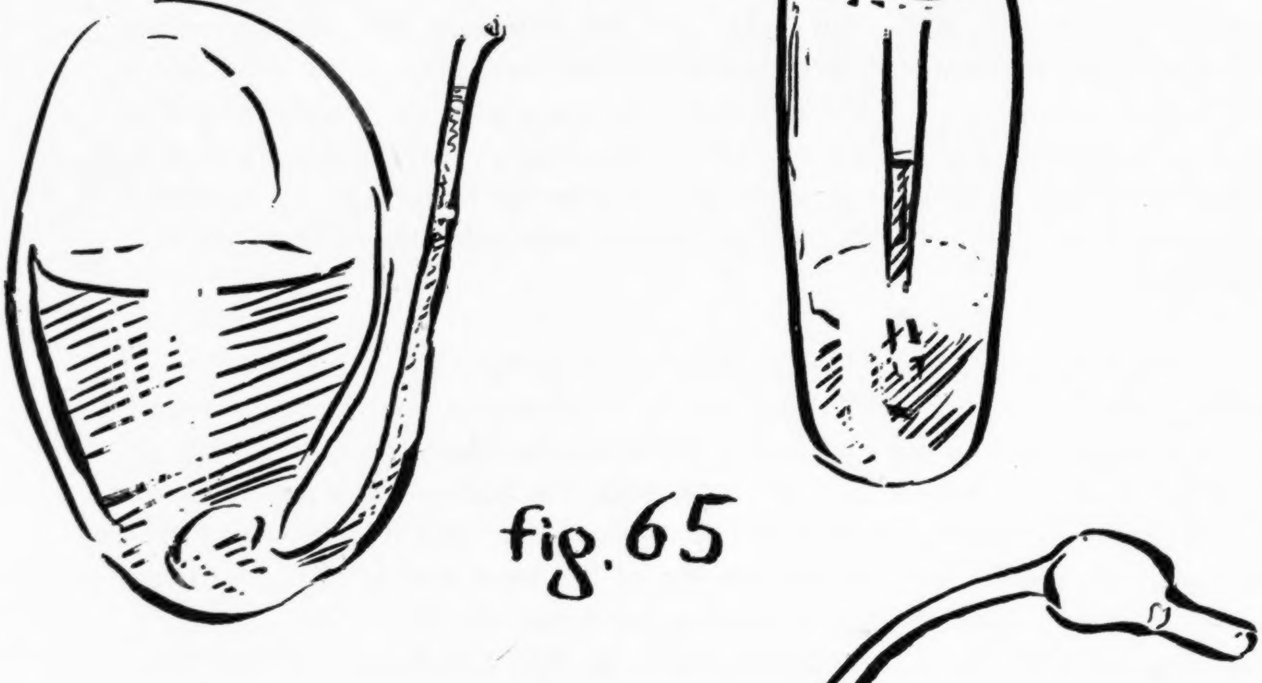


fig. 65

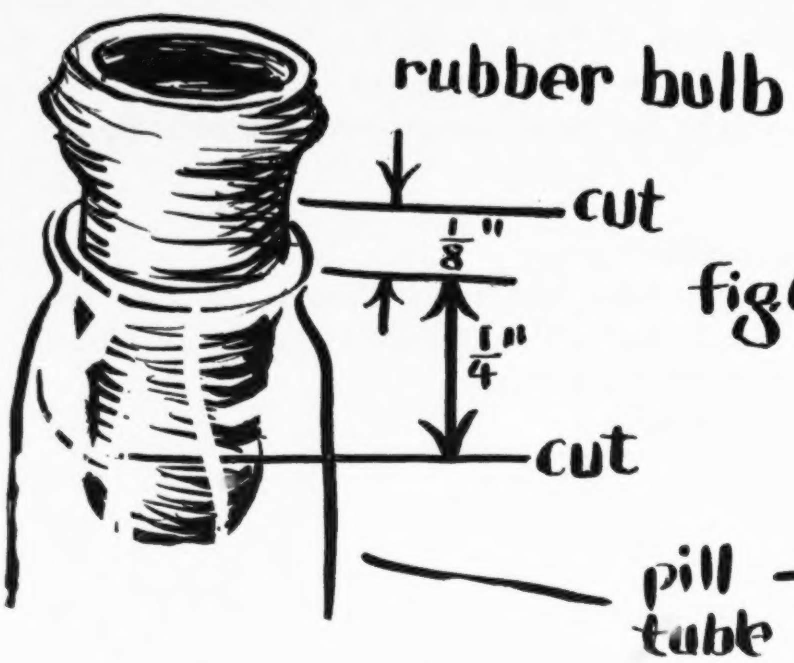


fig.66

rubber bulb
cut
1/8"
1/4"
cut
pill tube

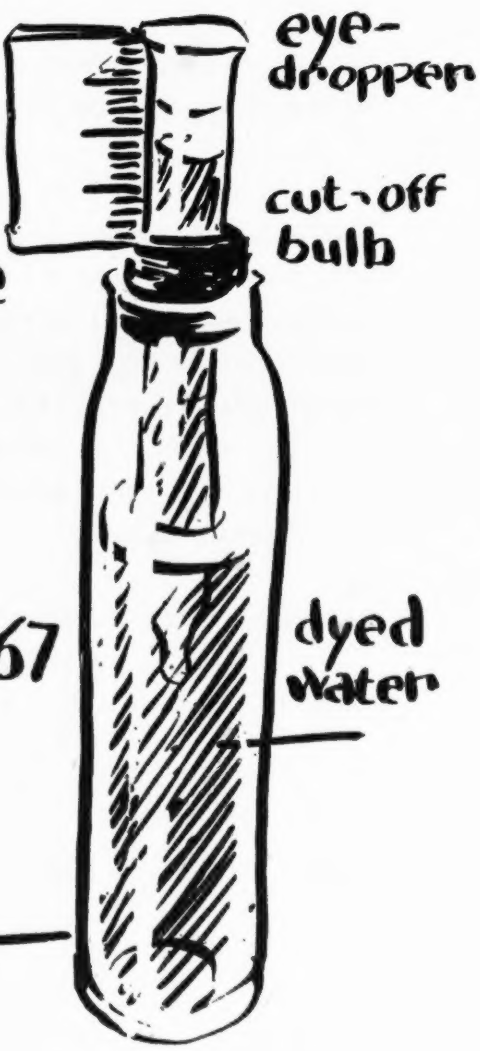


fig 67

eye-dropper
cut-off bulb
scale
dyed water
pill tube

31. Cooling Power.

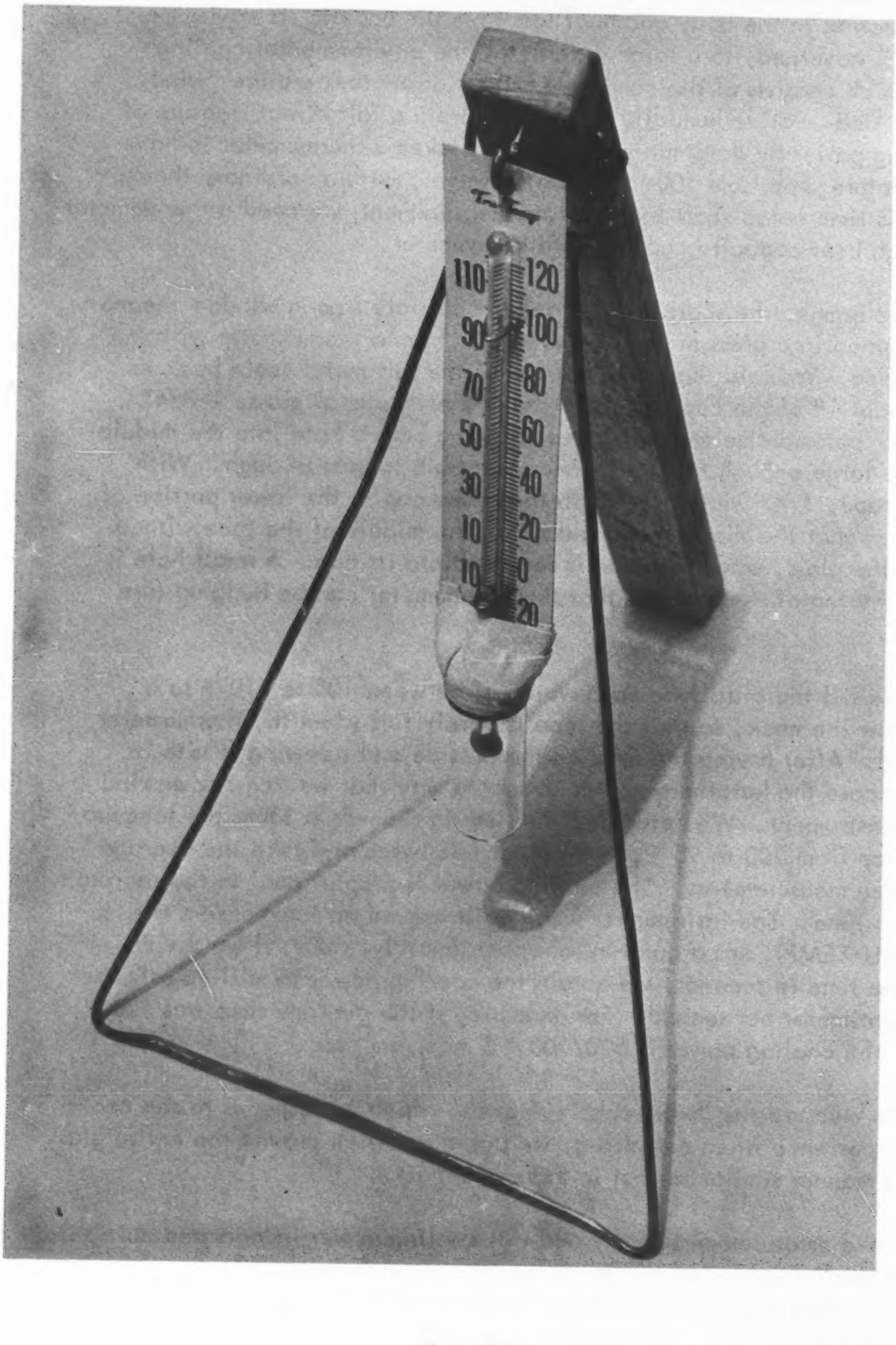

110
90
70
50
30
10
10
120
100
80
60
40
20
0
20

Plate 36.

Human comfort depends, among other things, on the balance between heat production in the body and heat loss from the body to its environment. Heat loss is governed, to a large extent, by the environmental cooling power, which consists of the combined effects of air temperature, wind, radiation, and relative humidity. We can obtain a fair direct measure of the cooling power by determining the time it takes a thermometer to have its temperature drop from 100 to 95°F. However, with an ordinary thermometer, this time is too short for accurate measurement; we need a thermometer with a high heat capacity, called katathermometer.

We remove the scale with attached capillary from a window thermometer mounted in a glass or plastic tubing, or from a thermometer with plastic frame. We fold the lower portion of the soft metal scale back to expose about 1" of the capillary. We take a pill tube of glass, 1-3/4" long, 1/2" outer diameter, with screw cap and bore a hole into the middle of the cap large enough for the thermometer bulb to pass through. With adhesive tape, 1/4" wide, we fasten the screw cap to the lower portion of the scale so that the thermometer bulb is in the middle of the tube without touching the glass, when the tube is screwed into its cap. A small hole is bored at the top of the scale so that the thermometer can be hung up (see Plate 36).

We fill the glass tube with water of between 105 to 110°F to a little below the neck, so that the tube is barely full when the thermometer is inserted. After drying the tube on the outside and screwing it into its cap we expose the katathermometer in such a way that we stand downwind from the instrument. We determine the time in seconds it takes the temperature to drop from 100 to 95°F. We repeat this twice and take the average of the three measurements. The cooling power is proportional to the reciprocal of this time. The instrument, when built around an inexpensive thermometer (TRU-TEMP), has a constant of approximately "500"; if we divide 500 by the time in seconds, we obtain the cooling power in millicalories per square centimeter per second. For example, if the average time was 100 seconds, the cooling power is 500/100 = 5 mcal/cm^2 sec.

To measure the "wet" cooling power, which corresponds to the cooling we experience when perspiring, we put a wet wick around the entire glass tube in a manner similar to that in Experiment 10.

Take measurements of dry and wet cooling power indoors and outdoors, in draft-free and windy environment, in sunshine and shade. 1. How does the cooling power depend on air temperature? On wind? On Radiation? 2. Is the dry or the wet cooling power greater? 3. What would be the dry cooling power, if the air temperature were 95°F or higher? The wet cooling power?

Material: One thermometer
One glass pill tube, 1-3/4" long, 1/2" outer diameter
Adhesive tape, small piece of thin cotton cloth, thread, warm water, watch or clock with second hand

Cost: 65¢

'32. Mirages.

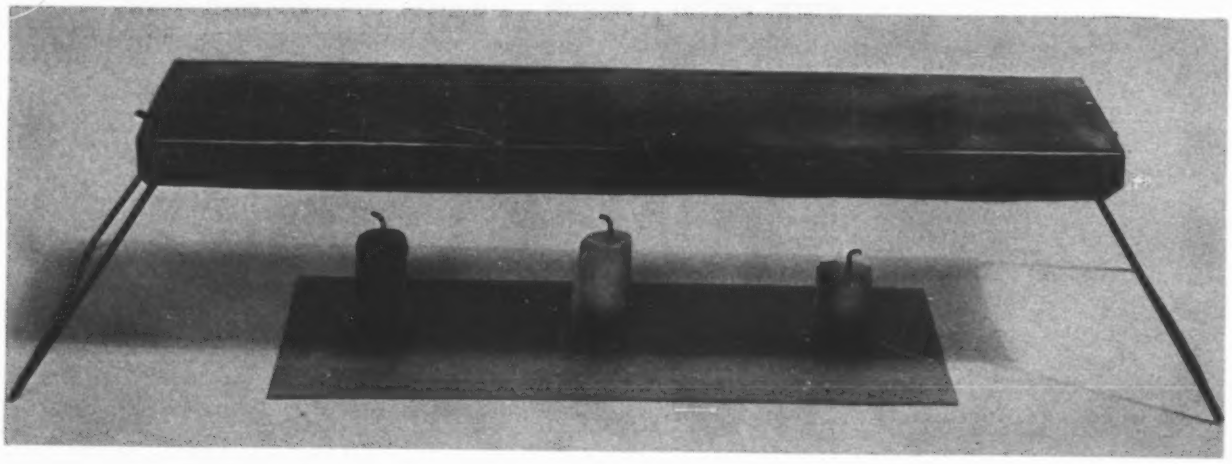


Plate 37.

When driving on a sunny day, one can often notice that there is, at a distance, what looks like water on the highway. However, when reaching the spot, the highway is dry. This is a mirage caused by a thin air layer being heated in contact with the hot pavement. The lower density of the hot air causes light rays from the background, often the sky, to be reflected by that layer. When the layer of low density is below the observer's eye, the phenomenon is called an inferior mirage. Sometimes such a very warm layer is aloft (temperature inversion) and causes a superior mirage. When a stone or brick wall is heated by the sun's rays and the air layer in contact with it becomes hot, this vertical layer produces a lateral mirage.

In order to see these mirages, we must look at a very small (grazing) angle over the hot surface. On a sunny day, lean a long stick against a stone or brick wall that has been exposed to sunshine for several hours, Go as far away as possible from the stick and place your eye as close to the wall as possible. You then will see the top of the stick apparently bent down as in Fig. 68.

We can produce a hot air layer in the laboratory with an electric hot plate that has a smooth, solid top. If we back a few feet away from the plate and place our eye at almost the same level with the hot plate, we can see reflections of distant objects in the hot air layer over the plate.

If no hot plate is available, we take a large tin can with uncorrugated side (such as cans in which vegetable shortening is sold), cut the bottom out, and cut the remaining cylinder along the welded seam. The top and bottom edges are trimmed off, so that the metal sheet can be flattened out. We then fold 3/4" of the two long edges at right angles to stiffen the sheet, the top of which will then be about 15" long and 3-1/2" wide (Fig. 69). The top surface is sanded, to remove the metal gloss; this can also be burned off or covered with candle soot, so that only reflections from the air layer but not from the metal are seen.

Cut off the hook and twisted neck of a wire clothes hanger and straighten out the remaining wire. Cut this into two equal lengths and bend each into the shape shown in Fig. 70. Near the ends of the folded sides of the metal sheet, punch holes big enough for the wire ends to go through. Then bend one end of each of the wire stands as shown in Fig. 71, so that the sheet will stand as shown in Fig. 69.

Put 4 or 5 candles (fastened to a piece of cardboard or tray) under the sheet and heat it well. At a distance of at least 12 feet place a straight stick at an angle so that you see it as in Fig. 72, when sighting across a short edge of the plate. You should be about 3 to 4 feet away from the plate, and your line of sight should barely pass over the heated surface. Then extinguish the candles and sight just under the plate. If you have someone hold the metal plate by the stands so that the surface is vertical, you can see a lateral mirage. Draw a picture of the shape of the stick as you see it.

Material:	One large tin can, uncorrugated Four or five candles One wire clothes hanger A sheet of cardboard, about 4 x 15"
Cost:	15¢

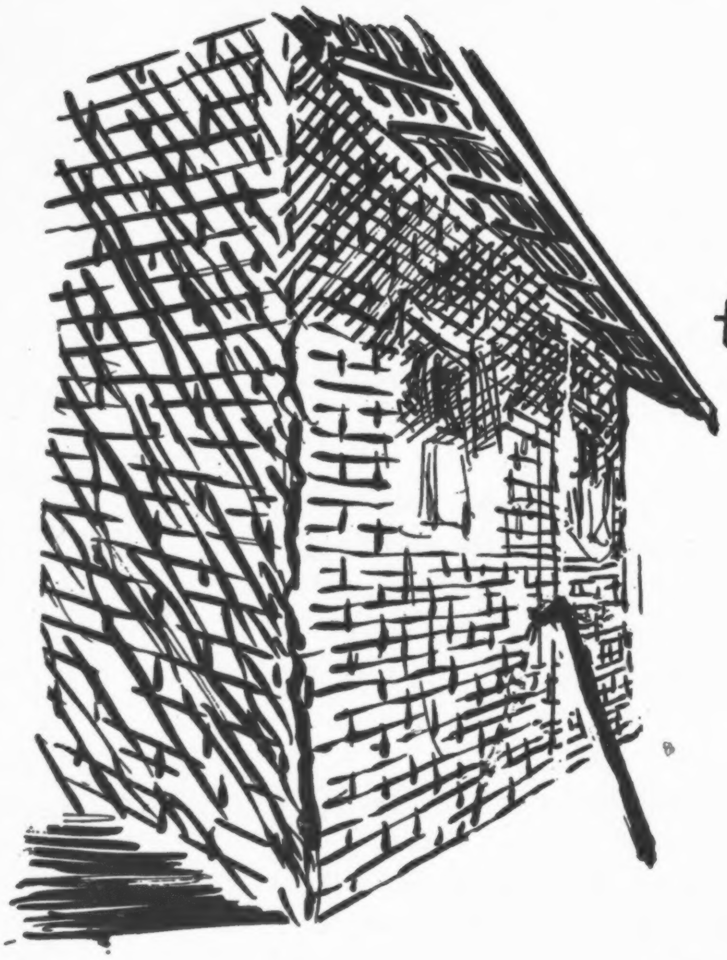
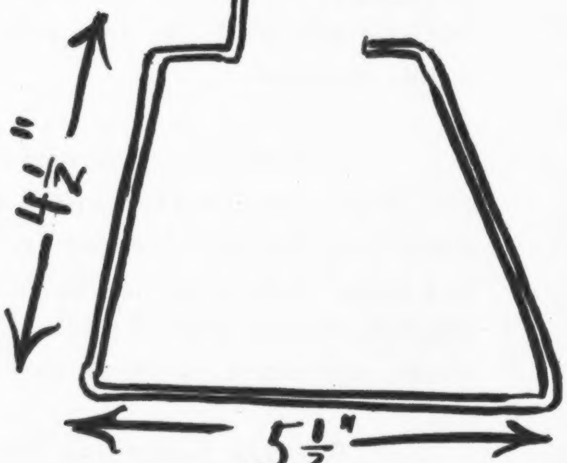


Fig. 68

fig. 70



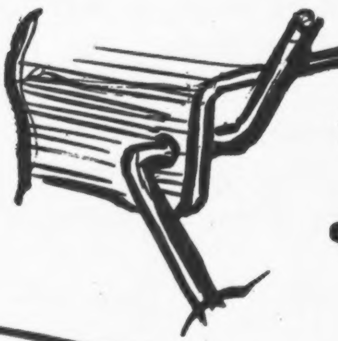
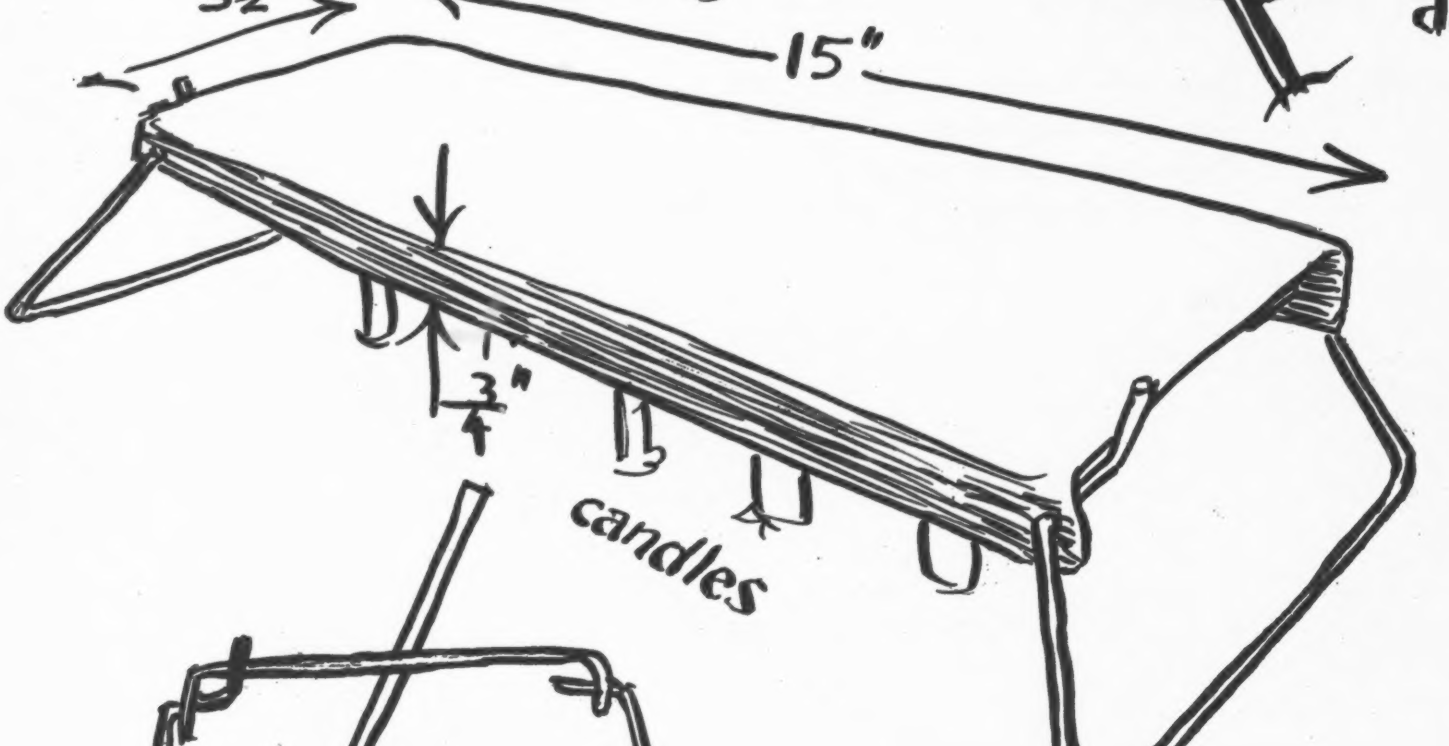


fig 71
detail

fig. 69


3½"
15"
3/4"
candles

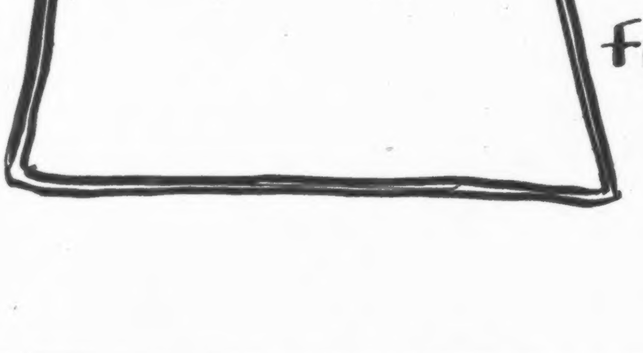


fig. 72

33. Scintillation or Atmospheric Boil.

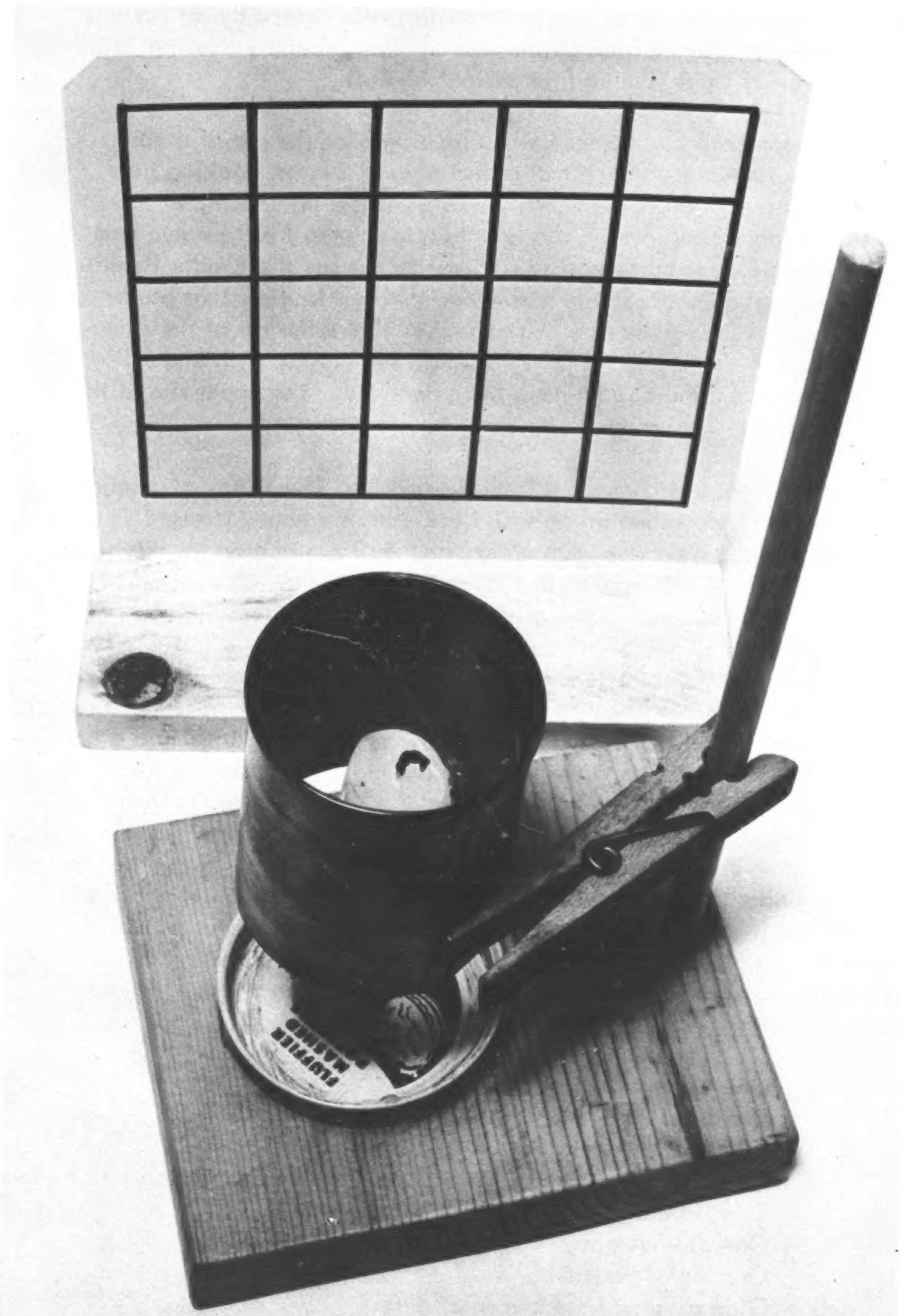

FLUFFIER
MASHED

Plate 38.

Astronomical scintillation causes the twinkling of stars; terrestrial scintillation, also called atmospheric boil or shimmer, causes distant objects to appear with fluctuating distortions. Scintillation is caused by air parcels of different densities moving through the line of sight, thereby causing varying refraction of light coming from distant objects.

This phenomenon can be seen when looking over the top of a car, parked in the sun, toward an object at a distance; in winter, looking over a heated radiator out through the window will show the shimmering of objects. In the laboratory, we hold a candle a foot or so from our eye and place a piece of metal or cardboard so that we do not see the candle flame; then we look at any object a few feet away so that our line of sight passes through the flame gases, about one or two inches above the tip of the flame. If there is a draft in the room, we have to shield the candle with a small tin can from which top and bottom have been removed. The upper rim of the can should be slightly above the flame tip.

The phenomenon becomes particularly striking, if we look at a square grid made on a sheet of cardboard on which we draw six heavy straight parallel lines up and down, one inch apart, and six lines across; for this we can use a grease pencil (eye-brow stick, lip stick, etc.) or ink applied with a fine brush or a pipe cleaner. The grid is placed six feet from the observer.

For repeated demonstrations of scintillation, it is convenient to make a simple stand for the candle with a shield that can be adjusted to various lengths of the candle. We stick a 1/4" or 3/8" dowel rod, 8 or 10" long, into a board of wood, 3/4 x 4 x 5" with an appropriate hole, and glue it fast. A small tin can without bottom and top, about 3" long and 2 to 3" diameter, is fastened to one of the fingertip ends of a clothes pin with cement or wire. The pin is clipped on the post and a metal jar lid is fastened with nails or cement to the base, directly under the can, and a short piece of candle is fastened in the middle of the lid (Plate 3B). The top rim of the candle is adjusted to about 1/2" above the tip of the candle flame. The target grid is drawn on a piece of white cardboard, 6 x 7", and nailed or glued to an appropriate piece of wood (approximately 1/2 x 2 x 6") so that it stands upright.

Material:	One piece of wood, 3/4 x 4 x 5" One piece of wood, 1/2 x 2 x 6" Sheet of white cardboard, 6 x 7" One 10" length of 1/4" dowel rod (a long pencil can also be used) One tin can 3" high, 2 to 3" diameter One clothes pin One metal jar-lid Glue or household cement, nails One candle
Cost:	15¢

34. Rainbow.

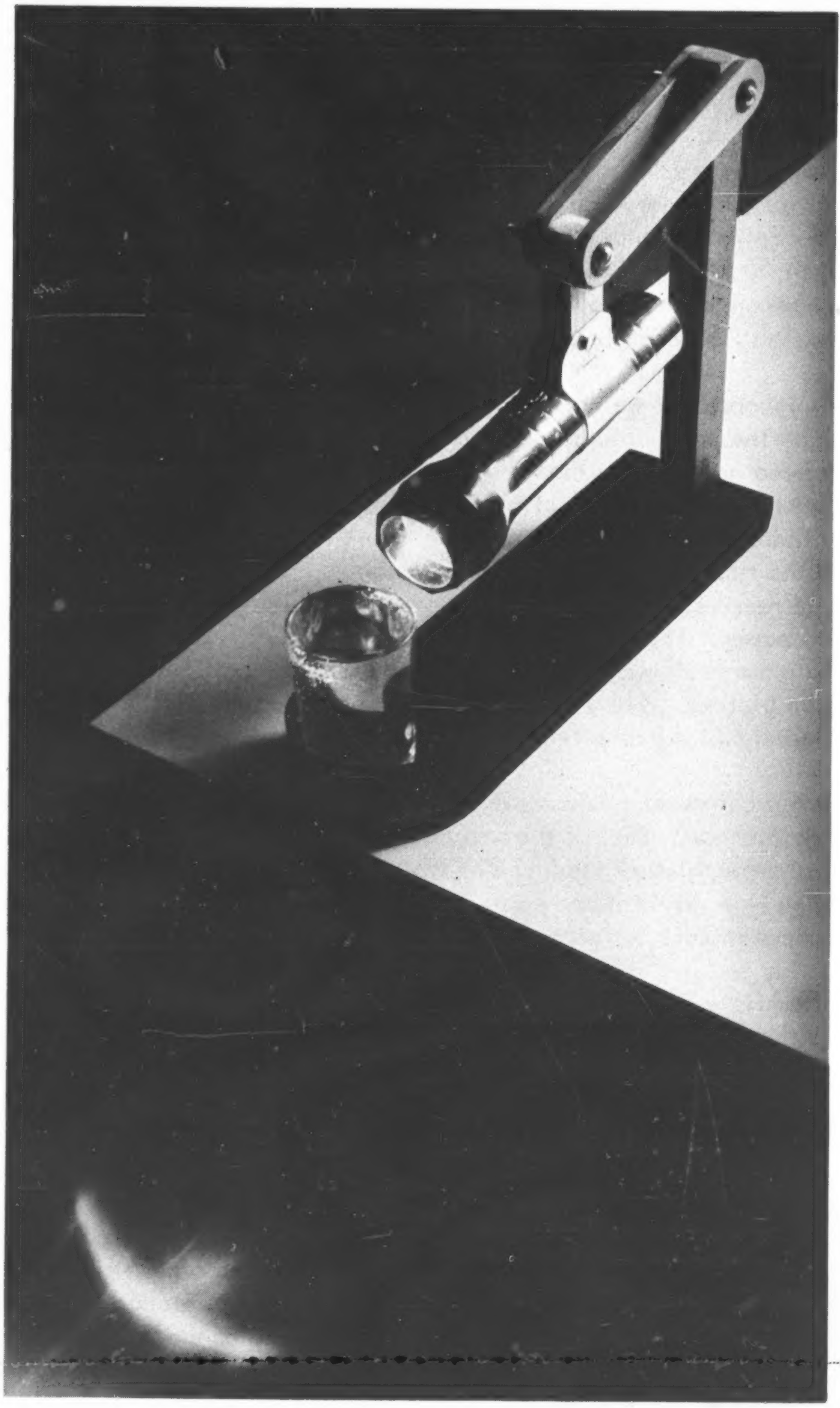


Plate 39.

Rainbows are produced by the refraction of sunlight going into and coming out of raindrops, with reflection of the light inside the drops. We can make artificial rainbows with a gardenhose and a sprinkler head adjusted for a very fine spray. Having the sun in our back and spraying water in a broad stream at an angle between 40 and 50 degrees around the shadow of our head, we can see a rainbow. Careful observation will show, that rainbows do not contain all the socalled rainbow colors, i.e. colors of the spectrum. Adjusting the nozzle of our gardenhose to produce different droplet sizes, we can observe changes in the colors. Under proper conditions, the secondary rainbow may also become visible; it has an angular radius of about 50 degrees, whereas the primary rainbow has one of 42 degrees. The secondary rainbow, produced by sunlight being twice reflected inside the droplets, is not as bright as the primary rainbow.

In the laboratory, we can make a model rainbow, which is however, not produced by the same processes as the real rainbows. We set a drinking glass, which need not be more than 3" high and 2" diameter, filled to the very top with water, at the edge of a table. The glass should preferably be a straight cylinder or only slightly tapered. There should be no design on the glass and the rim should be smooth. Air bubbles on the inside of the glass should be removed. On the floor below the table edge we lay a large sheet of white paper. Then we hold a flashlight at a very flat angle near the rim of the glass as shown in Figure 73; if available, the light beam of a projector can be used. The room should have only subdued light or be completely darkened for best effect.

1. What colors do you observe? 2. Is the color sequence the same as that of the primary rainbow? That of the secondary rainbow? 3. By what optical process is this model rainbow produced? Which process is missing that is present in real rainbows? 4. What is the cause of the arc shape of the natural rainbow? What is the cause in case of the model?

If a flashlight is used, it is suggested to clamp it on a stand in a position that produces the best rainbow. If a stand is not available, we can make one especially adapted for the purpose. A wooden post, 3/4 x 1 x 10", is attached to a wooden board, 3/4 x 3-1/2 x 12", the one end of which has been rounded. A strip of tin-can metal, 2 x 7", is nailed to the rounded end as guard rail for the glass of water (Fig. 74). At both ends of two strips of wood, 1/4 x 1x6", 1/4" holes are drilled, and one hole near the top of the post. The strips are bolted to the post, one on each side of it. Then we drill a 1/4" hole near one end of a piece of wood, 5/8 x 1 x 3", and bolt this between the other strip ends (Figure 74). Then we bend a strip of tin-can metal, 2 x 6", around the flashlight near its center of gravity, punch a hole through each end of the strip and fasten it to the support arm with wood screws as in Figure 74. The flashlight can then be moved into the best position and fixed by tightening the bolts.

Material:
One board of wood, 3/4 x 3-1/2 x 12"
One stick of wood, 3/4 x 1 x 10"
Two strips of wood, 1/4 x 1 x 6"
One piece of wood, 5/8 x 1 x 3" or 3/4 x 1 x 3"
One strip of tin-can metal, 2 x 7"
One strip of tin-can metal, 2 x 6"
Two bolts and nuts, two wood screws, glue, nails
One clear glass tumbler with water
One flashlight
One sheet of white paper.

Cost (exclusive of flashlight) : 15¢

fig. 73

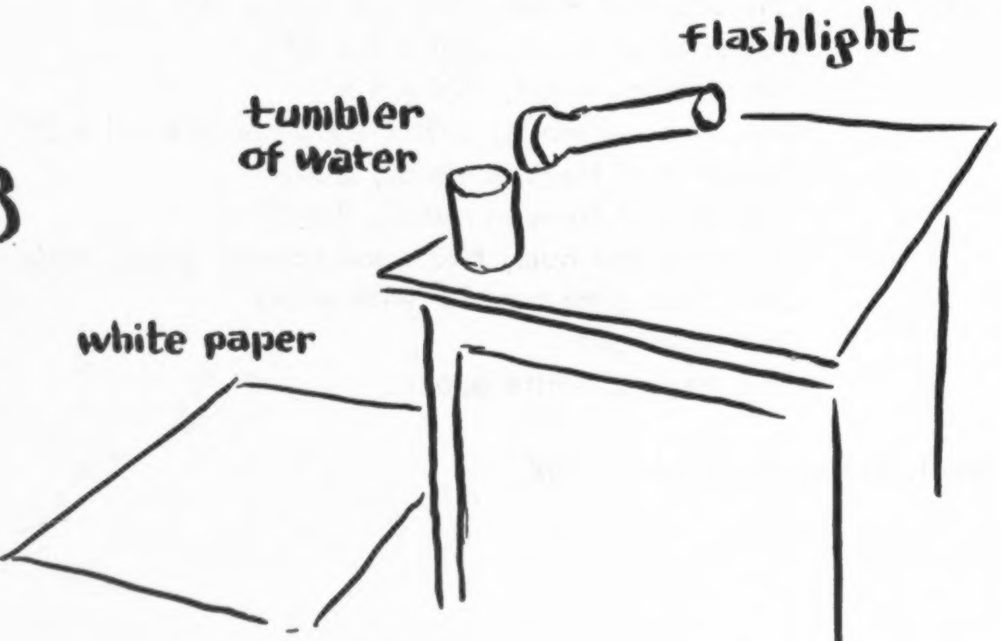
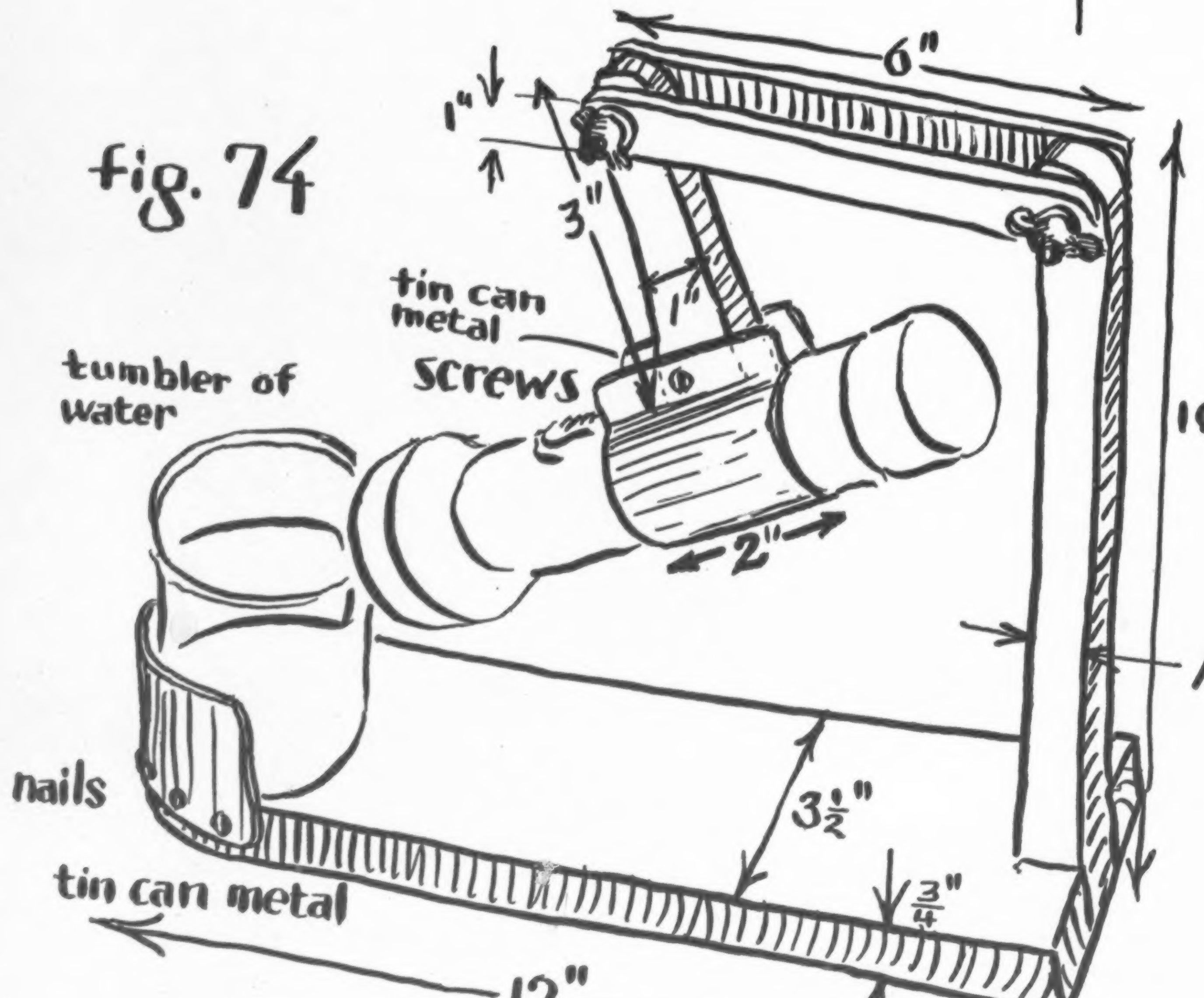

flashlight
tumbler of water
white paper

fig. 74


6"
1"
3"
1"
tin can metal
screws
tumbler of water
2"
10"
1"
nails
3½"
¾"
tin can metal
12"

35. Corona.

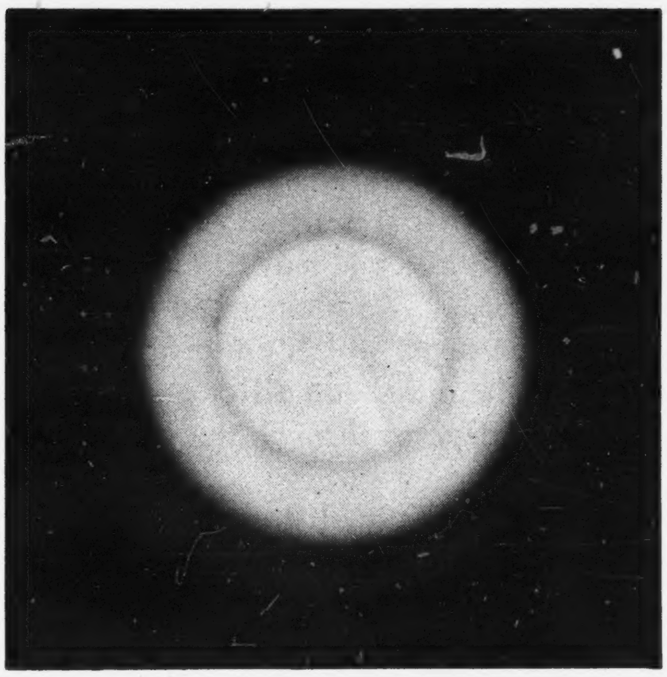


Plate 40.

The rings of small angular diameter, that appear around sun or moon on translucent clouds, are called coronas. A corona is produced by diffraction of light on cloud elements or dust particles. The ring diameter is larger for small than for large diffracting particles. The colors are arranged similar to those of a primary rainbow; however, the corona colors are much less developed than the rainbow colors. Coronas can also be seen around street lights or the headlights of approaching cars, when looking through a dusty windshield.

Coronas are easily produced in the laboratory. In a darkened room we look toward a strong point-light source, which should be at a distance of at least 12 feet from the observer. Such a light source can be made by taping a piece of cardboard with a small hole (1/8 to 3/16" diameter) in front of a flashlight (with good batteries) or to the lens of a projector. If we use a flashlight, we can use the stand made in Experiment 34 to hold it.

Breathing on a small piece of good window or picture glass or a 2 x 2" slide cover glass that has been thoroughly cleaned, and holding it close to our eye, we see a corona. If we cool the glass in a refrigerator for a while, dew will form on it when we take it out, which will last longer than the condensation from our breath.

Excellent coronas are produced on glass dusted with Lycopodium powder (the spores of a club moss) as shown in Plate 40. The spores from mushrooms, such as puff-balls, can also be used. The smaller the dust particles and the more uniform their size, the better will the coronas be developed. A bright corona is usually surrounded by additional rings.

Material:	A sheet of glass, 2 x 2" or larger A flashlight or slide projector A small piece of cardboard, tape

3

36. Reflection Halos.

Most halos are refraction phenomena in the vicinity of sun or moon; the refraction takes place on the tiny icy crystals of which cirrus-type clouds consist. There are, however, two halo phenomena, that are produced by reflection of light on the outer crystal surfaces, usually of hexagonal ice needles. When the long axes of the ice needles are in a horizontal position, a sun (or moon) pillar appears as a vertical shaft of light through the light source. When the principal crystal axes are in a vertical position, a horizontal beam of light appears through the light source and may, in rare cases, form a complete circle parallel to the horizon. This phenomenon is called parhelic circle because the parhelia, or sun dogs, which are refraction halos, lie on this circle. When, as is sometimes the case, sun pillar and parhelic circle are simultaneously visible, a cross appears through the sun.

Although it would be extremely difficult to make small ice needles all oriented in the same direction, we can easily make reflecting surface elements that are aligned in the same direction. We stroke the surface of a clean piece of glass (a 2 x 2" slide cover glass will do) all over with our finger tip in the same direction, say, parallel to a horizontal edge. Should our finger be exceptionally dry and free of skin oil, we make it slightly greasy. Then we look through the glass toward a point light source as in Experiment 35, holding the glass so that the stroke direction is horizontal. 1. What phenomenon do we see? 2. What causes this phenomenon?

We now turn the glass 90 degrees, so that the stroke direction is vertical. 3. What phenomenon do we see?

We then stroke the other side of the glass plate in a direction at right angles to the previous one. 4. What phenomenon do we see? The same phenomenon can be seen by looking through a piece of fine-mesh fly screen made of shiny metal.

Material: Same as in preceding experiment.

37. Blueness of Sky.

Plate 41.

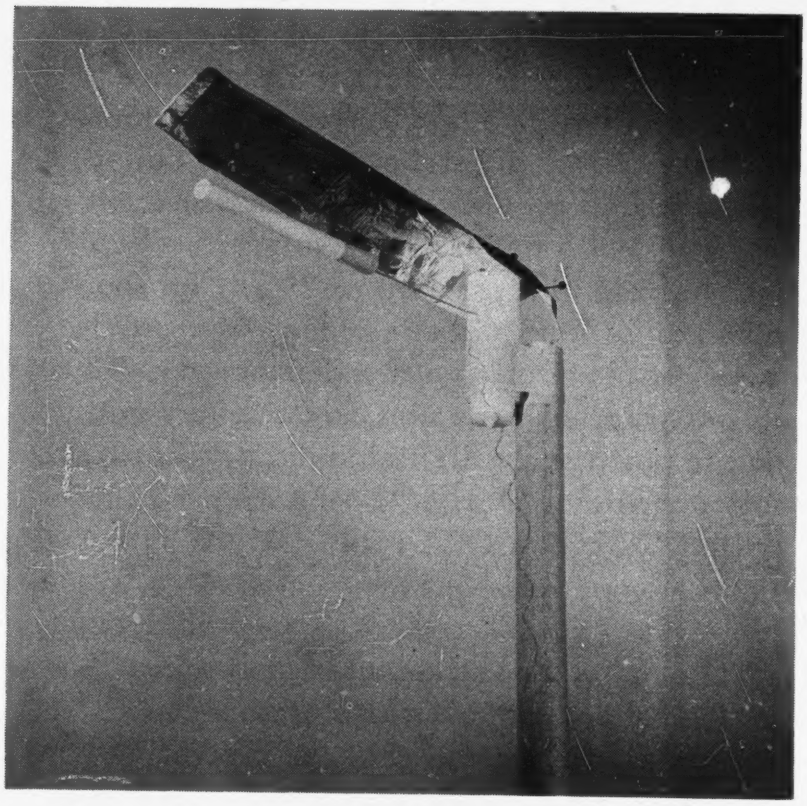
The molecules of the atmospheric gases scatter some of the sunlight. The scattering process involves preferentially the short wavelengths, if the scattering particles are small as compared to the wavelengths of light, as are the molecules. Therefore the light scattered by the atmosphere, the sky light, is blue. When the scattering particles are not small in comparison with the wavelengths, such as dust particles in the air, including condensation nuclei, the scattering involves more of the longer wavelengths. Because there is always some dust in the air, the sky light contains also longer wavelengths such as green and red, although the color mixture still looks blue. The more numerous and the larger the dust particles are, the more of the other colors are mixed with the blue, and the paler the blue becomes. For this reason, the sky is rarely seen as deeply blue in industrial as in rural areas. Also in humid air masses, in which condensation nuclei take on water vapor from the air, the sky is paler blue than in dry air masses.

We can imitate the process that causes the blueness of the sky by letting extremely small particles scatter sunlight or light from a very bright source (projector), looking at the scattering particles from a direction perpendicular to the light beam. Minute particles are contained in certain suspensions, such as soap in water (if the water is not too hard), milk in water, a weak silver nitrate solution, or "hypo" (photographic fixer).

Fill a glass container, such as a small fish bowl or bottle with smooth sides and rectangular horizontal cross section, with water and place a sheet of black paper behind it. Let a strong light beam fall on the container from the right or the left side. Put a few drops of milk into the water with an eye dropper, stir, and observe. Add more milk, stir, and observe the changes that take place. When the mixture shows a distinctly bluish color, look through it directly at the light source. 1. Describe your observations and explain the changes. 2. What is the color of the light source when looking at it through the liquid? Why? 3. Repeat the experiment using soap solution, made from a few soap shavings dissolved in a little hot water. Compare the results with the previous ones. If obtainable, use also silver nitrate which shows the effect particularly well, and hypo. If no ready-make hypo is available, we make a strong solution of sodium-thiosulfate in water and add a little vinegar. 4. Repeat the experiment with a corn-starch solution. What is the difference in color effect between starch and the other materials? Why? 5. Why are the skies generally deeper blue in cold air masses in winter than in warm air masses in summer? 6. Watch the smoke from a cigarette; what is the color of smoke coming from the glowing end and what is it when coming from the mouth of the smoker? What is the cause of the difference?

Material:	Glass container, preferably of rectangular cross section with smooth sides Eye dropper Some milk, soap, silver nitrate, photographic fixing solution, corn starch Water, black paper
Cost:	25¢

38. Atmospheric Electricity: Potential Gradient.



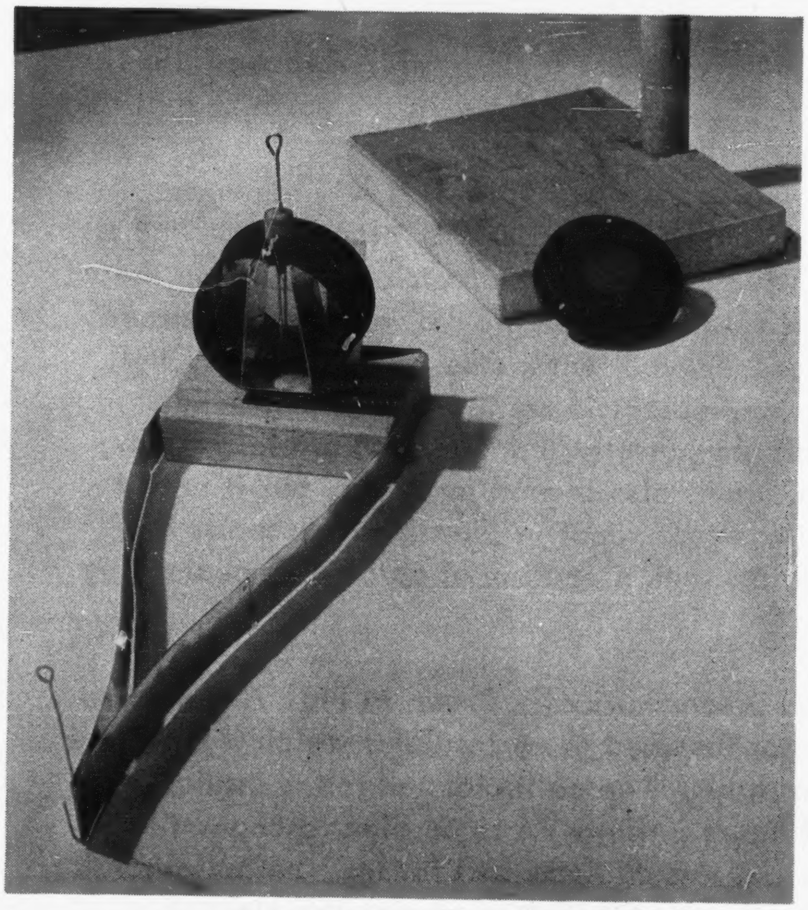


Plate 42.

Lightning is one of the most powerful manifestations of atmospheric electricity. However, there is, even in fair weather, electricity in the air that can be detected by means of simple instruments. The earth's surface is, on the whole, charged with negative electricity, while the air above it carries positive electric charges; this produces an electric field above the earth. (The signs of the charges are often reversed during thunderstorms.) Thus, we have between the air and the earth a difference in what is called electric potential. Over flat, unobstructed terrain this difference amounts up to several hundred volts between the earth and a point one yard vertically above it in the air. This is called the potential gradient or "PG", for short. The PG varies over a wide range of values from place to place, from day to day or from hour to hour at the same place. During a thunderstorm the PG may rise to several thousand volts per yard, and the sign may change rapidly from positive to negative and back to positive, as lightning discharges occur. Because this condition is extremely dangerous, DO NOT MEASURE POTENTIAL GRADIENTS DURING A THUNDERSTORM OR EVEN DURING THE APPROACH OF A THUNDERSTORM.

During fair weather, the PG is greater over elevated points such as houses, trees, hills, than over depressions in the surface or between houses, trees or other structures. In the immediate vicinity of a building or under or near a tree, no PG may exist, because such higher objects shield the space below them from the electric field (but not from lightning strokes).

Incidentally, the reason for our not "feeling" this electric field lies in the fact that we are "grounded" by our contact with the earth so that the field bends around and over us.

To measure the potential gradient, we need an electroscope and an electrically conducting probe which assumes the electric potential in the air at the point whose potential relative to the ground we wish to measure. Such a probe is called collector. The collector must be electrically well insulated against the ground or any object in contact with the ground. Very highly insulating materials are paraffin (candle wax) or sealing wax; either of these can be used. Glass is also a good insulator, but it easily acquires a film of water from the water vapor in the air which spoils its insulating quality. Covering glass with a coating of paraffin remedies this defect.

The equipment we need is schematically shown in Fig. 75 (see also illustration). We see a collector fastened to an insulator which is attached to a wooden pole about 2 yards high. The collector, which is insulated from the pole, is connected through a thin wire to an electroscope, the housing of which is grounded. As this equipment is set up, the collector has been in contact with the ground and therefore carries the electric charges of the ground, so that the electric field is bent around it. In order for the collector to assume the potential at the level, at which it is placed, and have the electroscope indicate the difference in potential between that level and the ground, we must disperse the electric charges. This can be done in several ways; the easiest are: 1) to let water drip off the collector, the drops carrying away the charges, or 2) to have the collector in a flame or burning fuse, the flame gases and smoke particles removing the charges on the collector.

The Electroscope. In order to make the electroscope very sensitive, we must keep its size small. Take a small tin can of about 2" diameter (such as a concentrated orange juice can) and cut away the cylinder about 1" from the bottom. Fit a cover on this shortened can, using a metal jar lid (the screw thread may have to be flattened out) or cut off another tin can about 1/4" from the bottom and flare in or out so as to make a well-fitting cover. The metal can of a typewriter ribbon can be used as is; if the cover is loose, the rim can be bent inward at 3 or 4 places to make it slide more tightly over the bottom part. This metal box is the electroscope housing. Cut circular holes of about 1" diameter approximately in the center of the circular sides, which become front and back of the electroscope (Fig. 76). If there is any varnish or paint on the can, remove it with sandpaper at least on the inside; for better looks also on the outside. Cover the holes with pieces of clear plastic or glass and glue with Duco cement or scotchtape them on the outside. Do not use seran wrap or similar material as windows, because the strong electric charge of such material spoils the electroscope.

Now punch two small holes through the middle of the top and bottom of the housing; widen the top hole to 1/4" diameter. Insert a short screw from the inside of the housing through the bottom hole and screw housing to a wooden block as base, with a couple of washers between housing and base, so that the housing cover can be easily put on and taken off. The base should be about 3/4 x 2 x 3". Cut from a tin can a strip of metal as wide as the inner depth of the housing (about 1") and about 4-1/2" long. Sand off any varnish or paint on both sides. Then bend strip as in Fig. 77. Place this in housing (Fig. 78) and fasten it to housing with a drop of cement (liquid solder is best) at one corner. (This strip brings the "ground" closer to the rod, to be constructed next, and makes the electroscope more sensitive.)

Take a piece of stiff wire 4-1/2 to 5" long (straightened paper clip) and bend into the shape indicated in Fig. 79. (This is the electrometer rod and the leaf will be hung from point A.) Cut a piece of a small candle about 1/2" to 3/4" long and 1/4" to 5/16" diameter (you can also mold a piece of paraffin or shave a piece of a larger candle to the required size). This is used to insulate the rod from the housing. Warm the upper rod end lightly in a candle flame and push it through the bottom of the paraffin plug, so that the rod is in the middle of the plug. Then bend upper rod end into a ring and insert rod assembly into the top hole of the housing so that the plane of the rod loop (the portion below A in Fig. 79) is perpendicular to the front and back of housing, or parallel to the plates inside. The rod should nowhere touch the housing or the plates. Fig. 80 shows the front view of the electroscope without cover.

The electrometer leaf is made from the aluminum foil of a cigarette package. (Household aluminum foil is too heavy and therefore not suitable.) Peel a strip of foil off its paper backing and cut a sliver about 3/4" long and as narrow as possible, but not more than 1/32", with fine scissors or razor blade. Straighten this leaf between your fingers and make a small hook at one end by bending over a piece of wire so that the leaf will look like in Fig. 81. This requires patience! Then hang the leaf by the hook at point A of rod in Fig. 79 so that it hangs free between the loop of the rod. The lower end of the leaf should be about 1/8 to 3/16" above the bottom of the loop; if leaf is too long, cut it off at bottom end with fine scissors. A pair of tweezers greatly facilitates the handling of the leaf. Finally close housing with its cover.

We now make scale out of a piece of white cardboard or stiff paper 1-1/2 x 2" in size. Draw on it a scale with divisions 1/32" apart; for easier reading, make every fifth division a little larger than the others (Fig. 82).

Cut two strips of cardboard (or metal from a tin can) 1/2 to 3/4" wide and 8 to 12" long, lay them end to end and scotch-tape them together. Bend a ring about 1/8" diameter at the end of a piece of stiff wire 4 to 5" long; this ring serves as eye piece to fix the position of the eye relative to the electroscope and the scale. Bend the cardboard strips at the joint with scotch tape on outside and place wire between the two legs at the joint, squeeze together and scotch-tape as shown in Fig. 83, so that wire can be pushed up or down for adjustment without sliding by itself. Spread the free strip ends apart and fasten to each side of electrometer base with glue or tacks as in Fig. 83. Now fasten the previously made scale to the base with glue or tacks behind the electroscope so that the position of the leaf as seen through the eye piece can be read on the scale through the electroscope windows (Fig. 84).

We only have to "ground" the electroscope housing and then we are ready to test the instrument. Wind one end of a piece of bare flexible wire tightly once around the washers between housing and base. Attach the other end to unpainted water or steam pipe, faucet, unpainted metal fence, or a metal rod stuck into the ground and watered. (If no wire is available, string or thread soaked in saturated salt water are also good electrical conductors, as long as they are moist.)

To test the finished electroscope, rub any plastic object (comb, toothbrush handle, ruler, etc.) on cloth. Bring this now charged object close to the top loop of the electroscope. When within a few inches of the loop, the charged object will deflect the leaf; with the leaf deflected to a position about half-way between rod and plate on the one or the other side, touch the rod top very briefly with your finger and remove the charged object from the vicinity of the electroscope. The leaf will now remain at an angle as in Fig. 85. (If the leaf is deflected too much and comes in contact with the plates, it discharges and has to be charged again. If the leaf does not move at all, tap the electroscope slightly or tilt entire instrument to check whether the leaf hangs free.) The deflected leaf should remain in practically the same position for at least 5 to 10 minutes. If it returns to the vertical position too soon, there is a leak in the rod insulation which happens when dust accumulates. This can be remedied by gently scraping the surface of the paraffin plug inside and outside the housing.

The Collector. a) Fuse Collector: Fasten with tape or wire a candle, about 6" long, to the top of a wooden stick (broom stick) of 5 to 6 feet length. Push a piece of stiff wire, 5 to 6" long, through the top of the candle, so that the wire sits fast. This is the collector wire. Fasten to it, near the candle, the one end of a thin wire, about 6 to 10 feet long; the fine wire of an old automobile spark coil can be used. The other end of this wire is connected to the top of the electroscope (Fig. 86). Push a 6" piece of hollow shoe string as a fuse over collector wire. A better fuse collector can be made by pushing the collector wire through the center of a cigarette, which is less likely to go out during windy weather.

b) Flame Collector: Tape a 6" piece of stiff wire (collector wire) to a candle as shown in Fig. 87; as protection from wind, make a cylinder of aluminum foil and fasten to the candle; punch a few holes into the foil below the candle wick, to let air into the cylinder for steadier burning of the candle. Another version of a flame collector can be made from a paper lantern by pushing the collector wire through the bottom and fastening it. The one end of the wire is bent so that it is in the candle flame; the other end is attached to the thin wire that leads to the electrometer. The lantern can be hung from the pole by means of nylon cord or strands of nylon thread as insulation, but the lantern must not touch the pole (Fig. 88).

c) Water-Drop Collector: Punch two holes near the top and on opposite sides of a tall, narrow tin can from which the top has been removed; with a piece of wire hang the can securely on a candle that has been fastened to the wooden stick at right angles, as in Fig. 89, in which also another way is shown of fastening the can electrically insulated from the stick. Punch a tiny hole (with a needle) near the bottom of the can through which water flows out of the can in a steady sequence of drops. Again a thin wire connects the can with the electroscope.

Measurements of Potential Gradient. Connect one of the collectors to the electrometer which should be placed on some firm support and grounded. Make sure that the thin lead wire hangs entirely free and does not come into contact with any object during the measurements. Light the fuse, flame, or fill can with water, respectively, and raise the collector slowly, until the electrometer leaf is deflected. It may be necessary to tap gently the electrometer housing to loosen the leaf. When the leaf is about half-way between rod and plate, note the position of the leaf on the scale and have someone measure the height above the ground of the fuse, candle flame, or hole from which water drops issue, respectively. The reciprocal of this height (measured accurately to the nearest inch or so) is then a relative measure of the PG: the greater the height, the smaller the PG. One also can raise the collector always to the same height and determine the amount of leaf deflection on the scale, which is then directly a measure of the PG. If the PG is too great, the leaf may touch the plate and be discharged. For this reason the measurement of the height for the same leaf deflection is a more convenient method. However, it may then be necessary to lengthen the pole on which the collector is fastened, in order to achieve the same deflection every time.

Make these measurements in the middle of a free area, away from any obstructions such as houses, trees, etc. Then repeat the measurements at intervals of several yards approaching the nearest obstruction. During the measurements, make sure that the fuse (or candle) is burning or water is still dropping off the can, respectively. How does the PG change as you approach the obstruction?

Materials:
Electrometer: Tin can 2" diameter
Two sheets of clear plastic 1-1/2 x 1-1/2"
Wood 3 x 2 x 3/4"
Two strips of cardboard or tin can metal, 1/2 x 8"
Two pieces of stiff wire (paper clips) each 4-1/2" long
Short piece of candle 1/4" diameter
Several feet of thin, flexible ground wire (from old automobile spark coil, e.g.)
Strip of tin-can metal, 1 x 4-1/2"
Piece of white cardboard 1-1/2 x 2"
Small screw and two washers; thumb tacks
Small piece of aluminum foil stripped off cigarette wrapper
Cement (liquid solder)

Fuse Collector: Ten feet of very thin wire (flexible), from an old automobile spark coil, telephone relay coil, or similar source
Candle 6' long, 1" diameter
Stiff wire 5 to 6" long
Stick of wood 6 feet long (broom stick, dowel rod, etc.)
Tape
Cigarette
For other collectors see text

Cost: 50¢

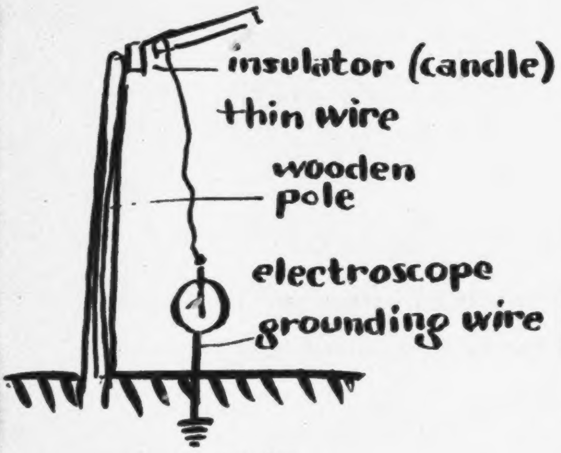

insulator (candle)
thin wire
wooden pole
electroscope
grounding wire

fig. 75

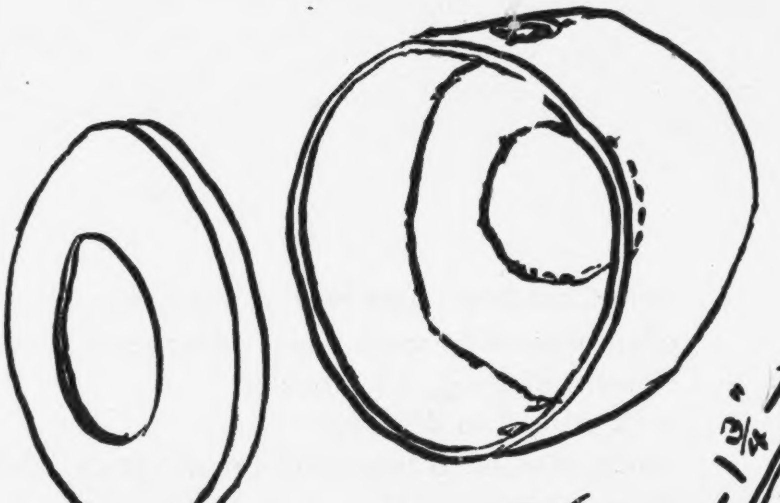
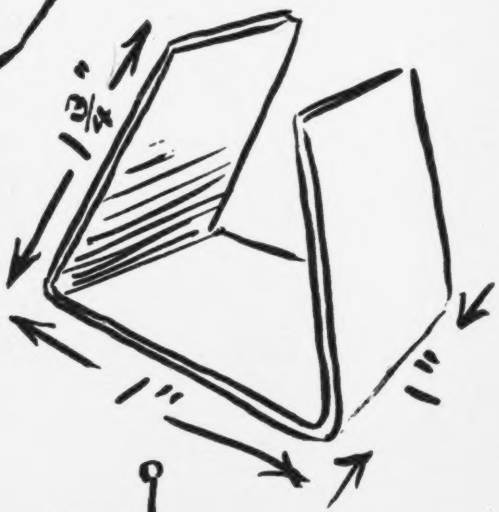


fig. 76

fig. 77



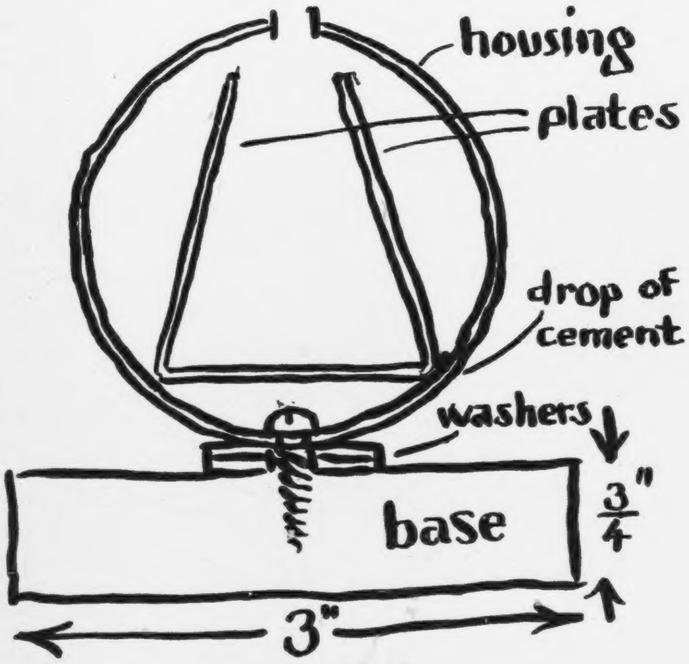

housing
plates
drop of cement
washers
base
3/4"
3"

fig. 78

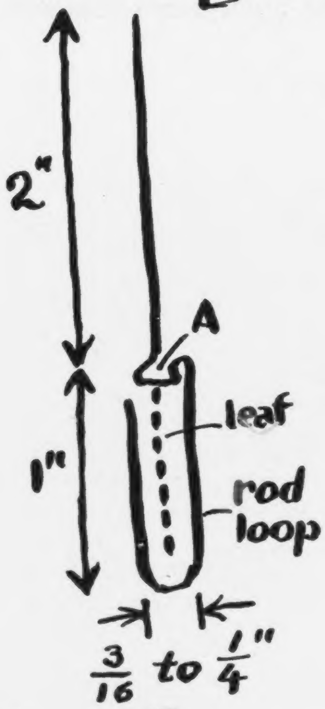
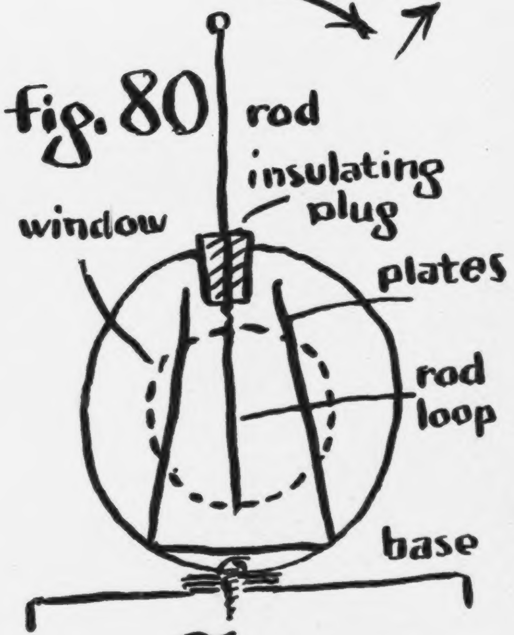

2"
A
1"
leaf
rod loop
3/16 to 1/4"

fig. 79

fig. 80


rod
insulating plug
window
plates
rod loop
base

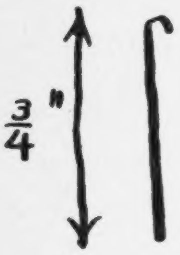


fig. 81

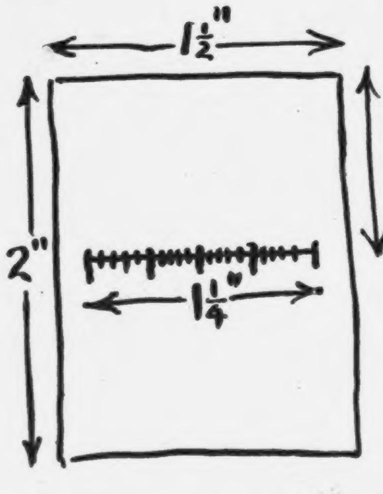


fig. 82

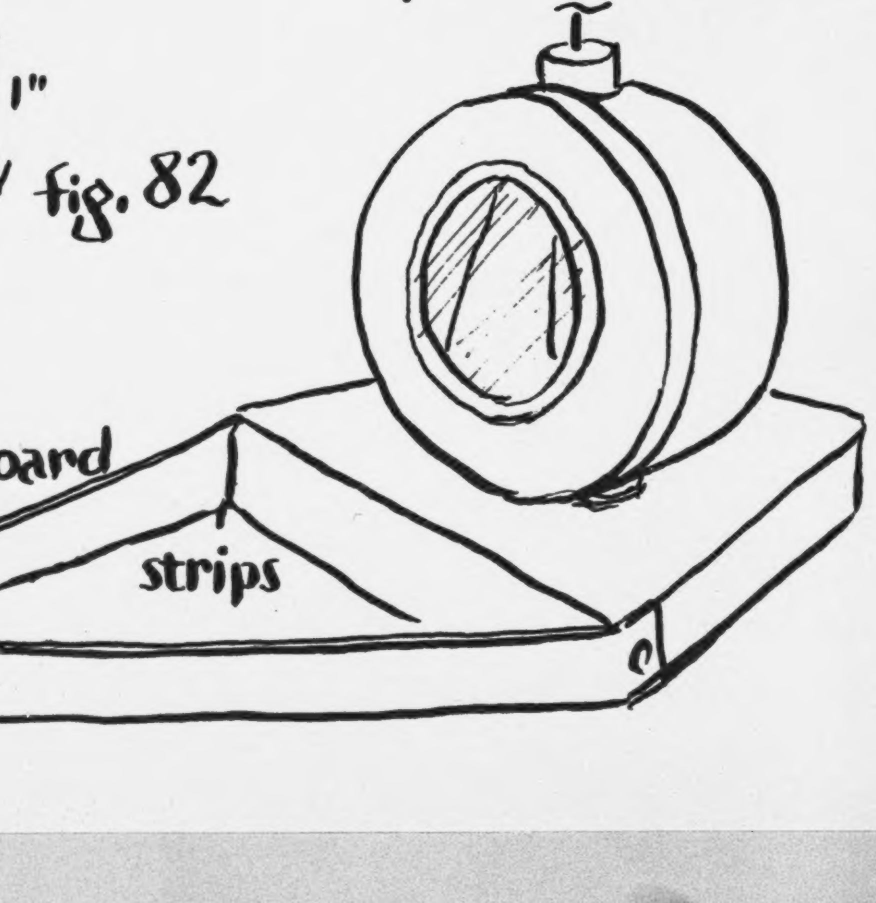

eye piece
cardboard
strips
scotch tape

fig. 83

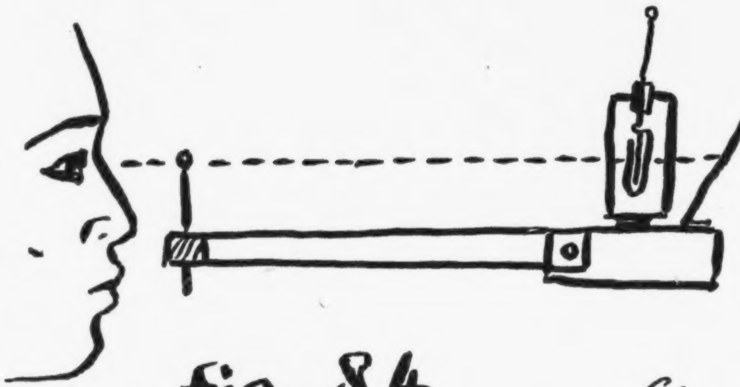


fig. 84

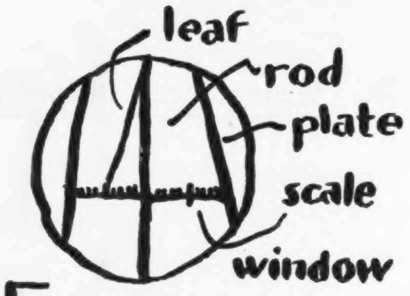

leaf
rod
plate
scale
window

fig. 85

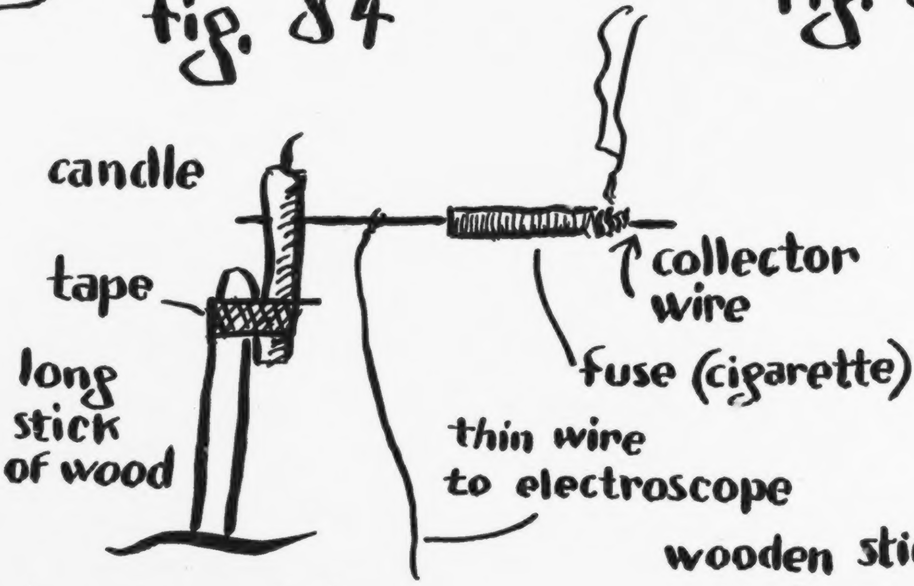

candle
tape
long stick of wood
collector wire
fuse (cigarette)
thin wire to electroscope

fig. 86

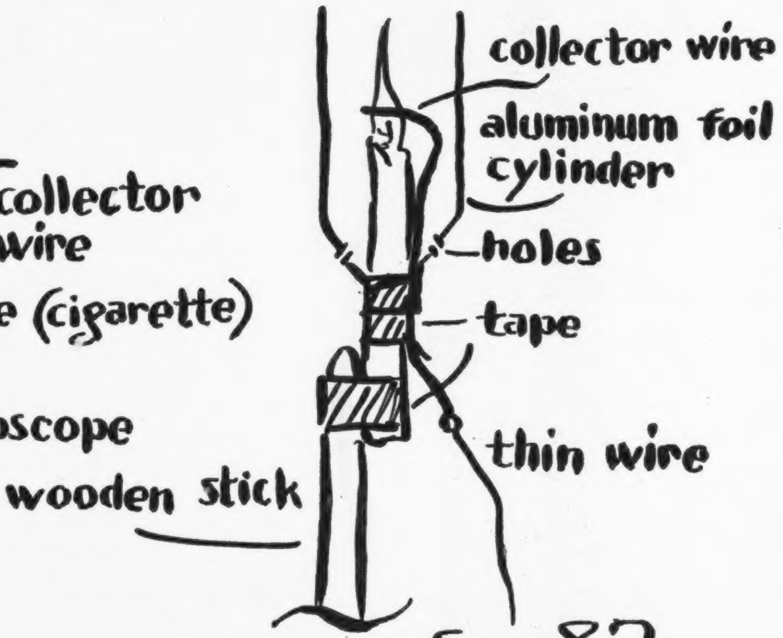

collector wire
aluminum foil cylinder
holes
tape
thin wire
wooden stick

fig. 87

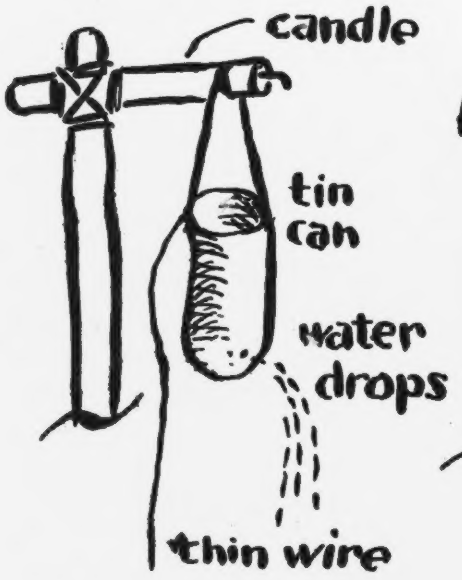

candle
tin can
water drops
thin wire

fig. 88

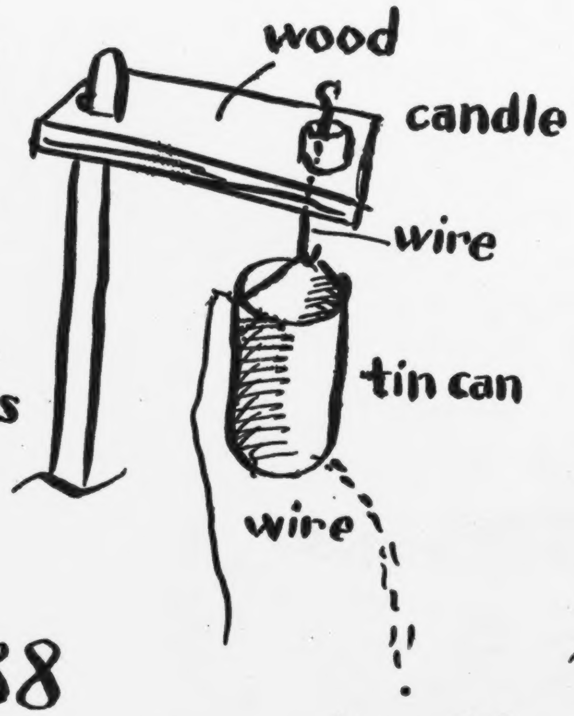
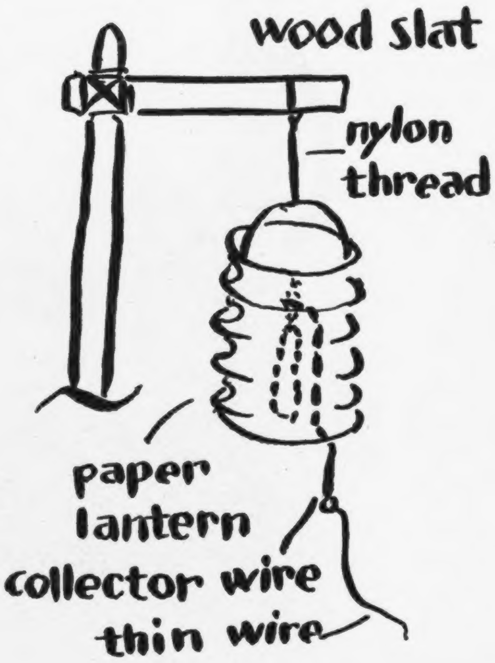

wood
candle
wire
tin can
wire

fig. 89


wood slat
nylon thread
paper lantern
collector wire
thin wire

39. Water Spray in an Electric Field.

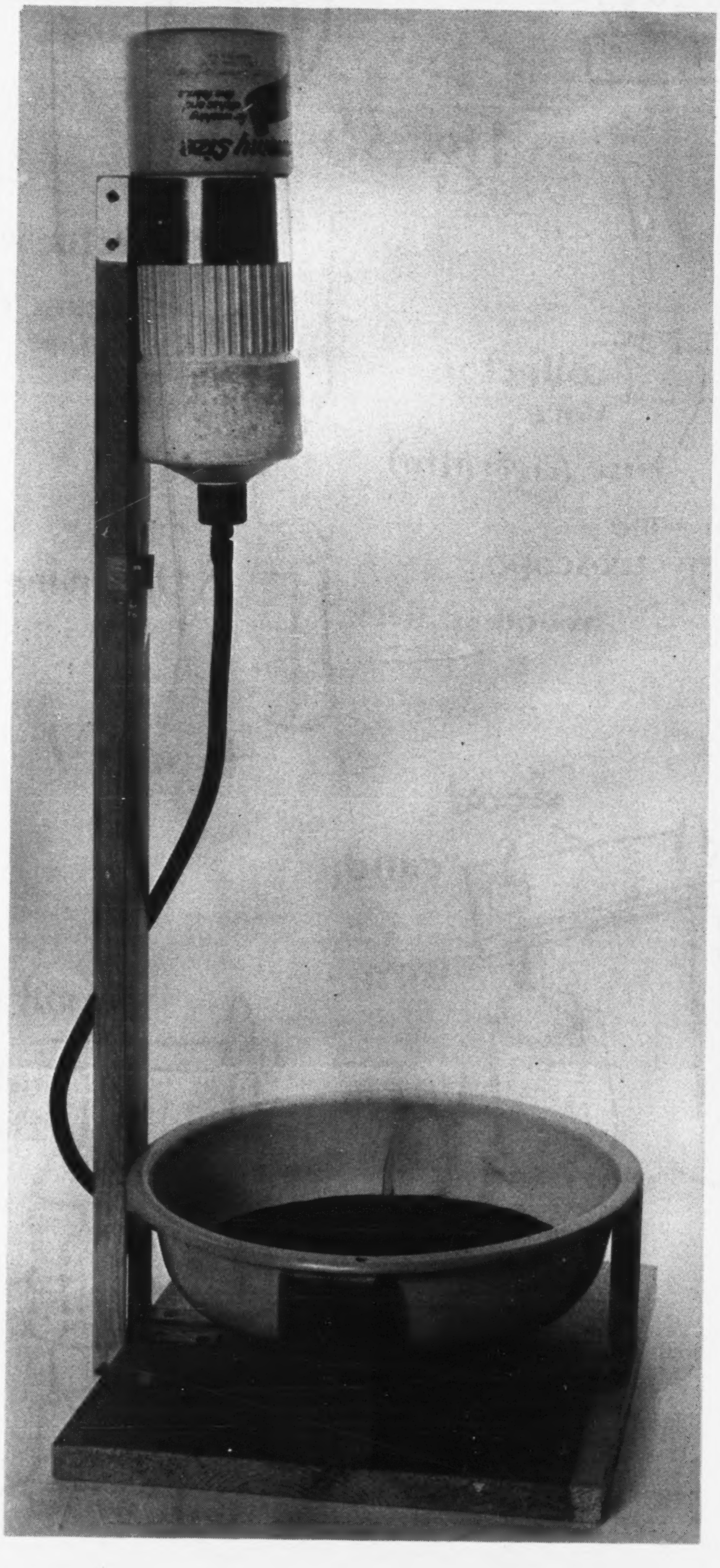


Plate 43.

The peculiar structure of water becomes particularly noticeable on freshly formed water surfaces which occur in all water sprays. The outermost water surface consists of a dipole layer with the negative charges on the outside. When we spray water through a fine nozzle which produces very small water droplets, and let these droplets fall on a still water surface, we see many droplets roll on the water surface before finally coalescing with it. Furthermore, if we bring an electric field in the vicinity of the spray, the stream of water droplets will be deflected, and the water droplets will coalesce.

a) To demonstrate this phenomenon, we need a bowl with fresh water, a source of water (faucet or bucket with water), a length of rubber or plastic hose (to connect with the faucet or to siphon water from a bucket), and a fine nozzle. A nozzle can be made from an eye-dropper glass tube by holding the small end into a flame (best is gas flame, especially Bunsen burner), rotating it in the flame until the glass is soft, and then pulling, with a pair of tweezers or pliers, the softened tip quickly into a fine capillary. After the glass has cooled, we break off the end as shown in Fig. 90. We connect the capillary with the water source and let a fine spray fall onto a water surface in a bowl. (If the bowl is made of plastic, it may be necessary to line its inside with aluminum foil, because plastic often acquires static electricity and thereby causes an electric field in its vicinity). We should observe many droplets rolling on the water surface. Now we rub any plastic object (comb, fountain pen, etc.) on cloth to charge it, and slowly bring it near the bowl. 1. What happens to the rolling droplets? 2. What happens to the spray, when the charged object is brought near it? 3. What happens to the spray, when a charged object is brought very near the nozzle from which the spray emerges? Can you explain the behavior of the water spray in an electric field? Note: It will be necessary to dry and recharge the object repeatedly.

b) We can make a more permanent and portable demonstration model; this consists essentially of a stand to hold the water reservoir for the spray and the bowl with water in the center of which the nozzle is mounted to produce a fountain effect. The fountain bowl is hanging by its rim supported by pieces of wood (Fig. 91), so that the rubber hose and nozzle have space below the bowl. The water reservoir can be made of a tin can, but a large plastic bottle (from household detergents) is easiest to work with. We drill a hole through the screw cap and cement a piece of copper or glass tubing or the rubber hose directly into it. (See similar procedure in Experiment 18.) With a sharp knife the bottom is cut out of the bottle which is then fastened upside-down with a strip of metal from a tin can to an upright piece of wood 2 to 3 ft. long, 2" wide and 3/4" thick. This wood stick is fastened to a wooden base 1 x 12 x 12" with glue, nails, and an iron "L" or angle and screws. A hole, just big enough to receive the nozzle, is drilled or punched into the center of a bowl of aluminum or plastic (enamel is not suitable) of about 12" diameter, 2 to 5" deep. The nozzle is inserted from below and cemented to the bowl; see also Experiment 18 for a method for fastening the nozzle to the bowl bottom. At three or four places, the bowl is supported at its rim by pieces of wood of appropriate sizes (see Plate 43), nailed and glued to the base. The bowl is filled with water so that the water level remains below the tip of the spray nozzle.

The reservoir is filled with water; to get the fountain started, it may be necessary to squeeze the hose along its entire extent to get all the air out. Also make sure that the capillary of the nozzle is not clogged; if this is the case, the particle clogging the capillary is carefully pushed down with a fine bristle or hair-thin wire and rinsed out at the bottom of the nozzle. To stop the fountain, the hose can be clamped shut.

Material: a) Eye dropper
2 ft. plastic or rubber hose
Bowl with water and a plastic object (comb, etc.)
b) One quart plastic (or metal) bottle with screw cap
(detergent bottle)
One aluminum or plastic bowl, 12" diameter, 3" deep.
Two eye droppers
30" rubber or plastic hose to fit eye droppers
Wood board 1 x 12 x 12"
Wood stick 3/4 x 2 x 30"
Three or four pieces of wood 1/2 x 2 x 4"
One strip of tin-can metal 2 x 12"
One iron "L", 1" wide, 3" length of the legs
Nails, glue, screws
A plastic comb or similar object and cloth, water.

Cost: $1.00

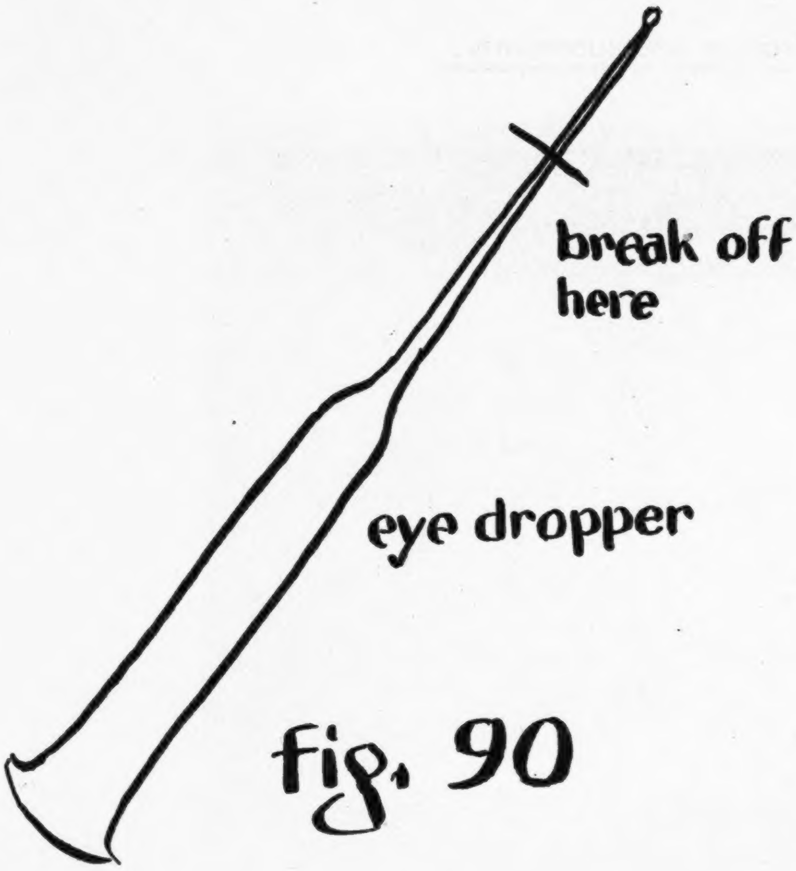

break off here
eye dropper

fig. 90

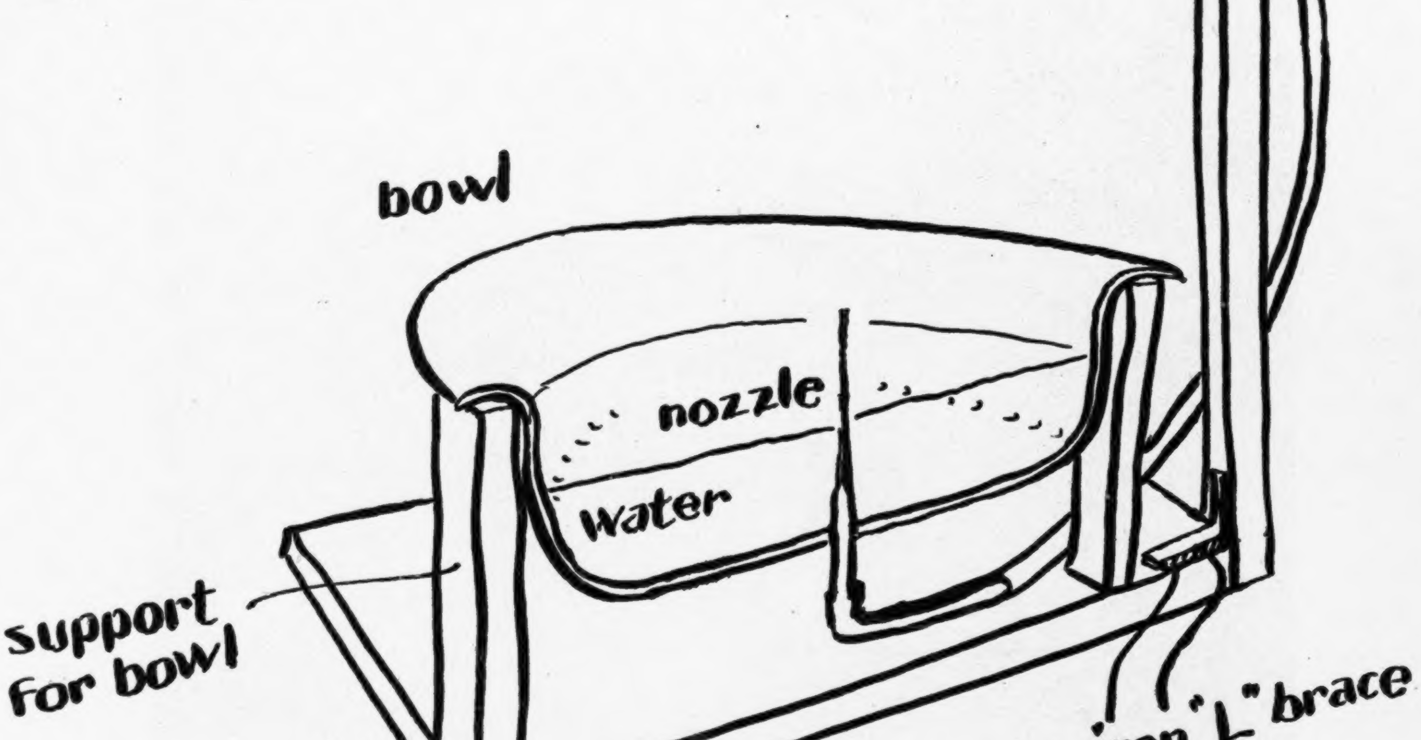

metal band
water reservoir (plastic bottle)
rubber hose
bowl
nozzle
water
support for bowl
base
iron "L" brace

fig. 91

V. OBSERVATIONS

40. Dry-Bulb and Wet-Bulb Temperature Measurements.

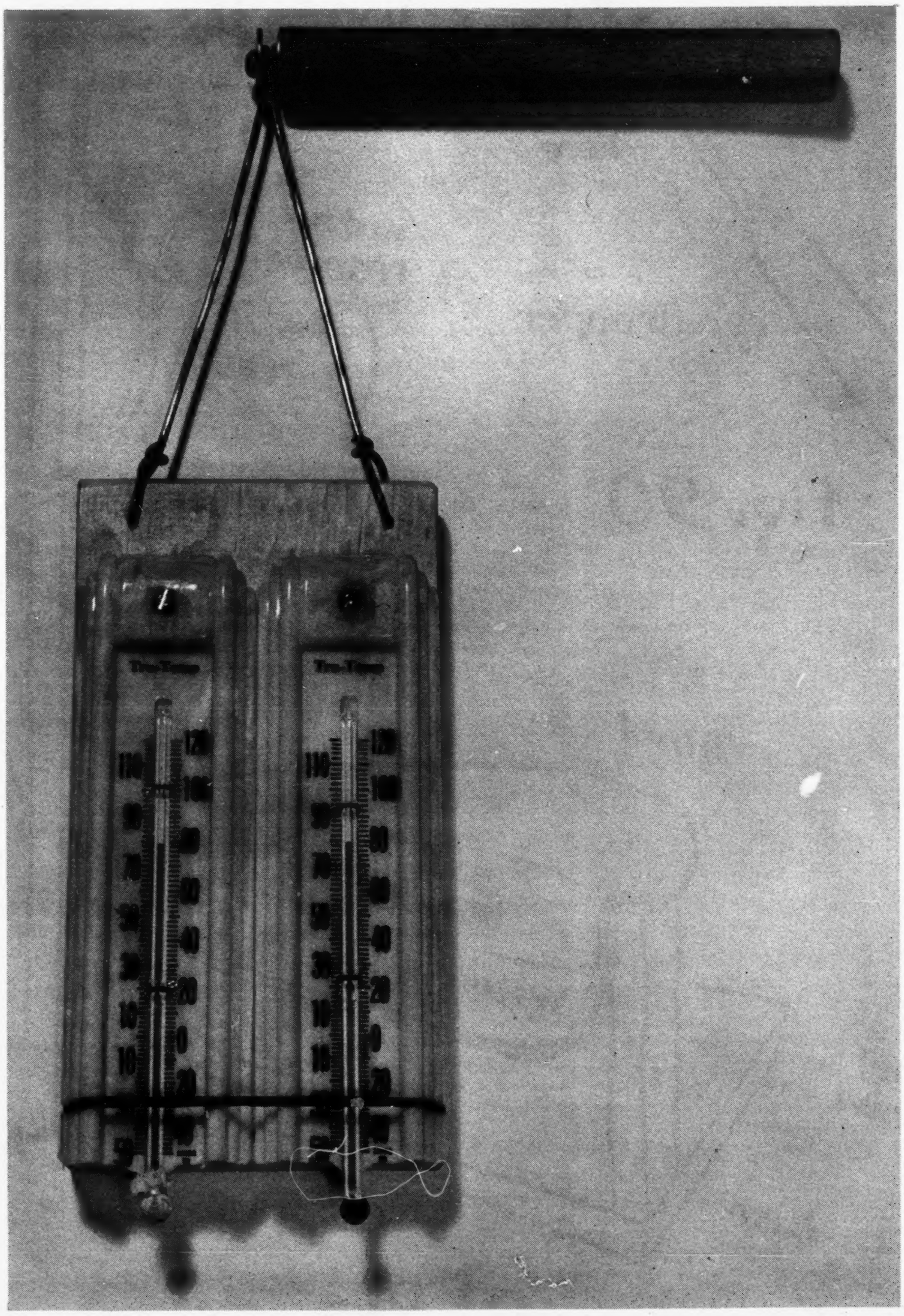


Plate 44.

An instrument which consists of a dry-bulb and a wet-bulb thermometer mounted together, is called a psychrometer. This is the most reliable instrument for measuring humidity; the rate of evaporation of water from the wet-bulb, and therefore the cooling of the wet-bulb, is a function of the relative humidity (see Experiments 9, e and 10).

Cut very carefully with a fine saw blade the lower end of the holders of two identical thermometers away, so that the bulbs and about 1/8" to 1/4" of the capillaries above them are free. Be extremely careful not to disturb the mounting of the capillaries on the scales and not to break the thermometers. Then take a piece of wood board as wide as the two thermometers side by side and one inch longer than the length of the remaining thermometer holders; the thickness should be at least 3/8" or better 1/2". Drill (or burn with a hot nail) two small holes 1/2" from one of the short edges (Fig. 92). Then wind the middle of a straight stiff wire 15" long and not less than 1/16" thick (clothes hanger wire) twice around a 1/8" screw to make a loose-fitting loop as in Fig. 93. Insert the wire ends through the two holes in the board and twist the ends as shown in Fig. 93, so that the assembly is 12" long. Make a handle of good wood (best is a dowel rod) 6" long and 3/4" diameter and fasten the wire loop to the handle end with a screw putting the loop between two washers. The screw should be tightened so that the board can be slung around the handle; since there is considerable centrifugal force acting on the board, the screw must be sturdy and sit well in the handle. Finally, the two thermometers are fastened to the board with screws so that the thermometer holders are flush with the lower board end. Cut a notch on each side of the board about 1/2" from the bottom and put two good rubber bands through the notches around board and thermometers. A circular piece of white thin cotton material, about 1" diameter, is wetted with water, put around the left thermometer, and tied around the capillary with white cotton thread (see Experiment 10). This is the wet-bulb wick. The excess material and thread is snipped off.

For outdoor measurements select a free place in the shade, hold the sling-psychrometer at arm's length and shoulder height, and swing the thermometers around the handle at a rate of three times a second. After a minute read quickly (without touching the thermometers!), first the wet-bulb, then the dry-bulb thermometer to the nearest 1/2 degree, if possible. Then continue to swing the thermometers until two successive readings show no more changes.

With the aid of psychrometric tables (which can be found in many elementary textbooks or can be purchased from the Superintendent of Documents, Government Printing Office, Washington, D.C., for 25¢), the relative humidity and the dew point can be determined. When no psychrometric tables are available, the relative humidity, R.H., can be roughly determined with the rule-of-thumb:

$$R.H. = 100 - 300 \frac{D - W}{D},$$

where D is the dry-bulb reading, W is the wet-bulb reading.

Take readings daily at the same time together with other meteorological observations. Always make sure that the wick is thoroughly wet; this may pose difficulties in very dry weather, when the wick may have to be wetted again several times, before a final reading is obtained. In this case it will help to use water that has a temperature several degrees below the lowest wet-bulb temperature obtained before the wick started drying out. 1. Will the R.H. be too high or too low, if the wick is not completely wet? 2. If the final wet-bulb temperature reading is taken without sufficient ventilation (by not swinging the psychrometer long enough) what will be the R.H. error?

Materials:	Two identical thermometers Wood board 3/8 x 4 x 8", approximately Stiff wire, 15" long, 1/16" diameter Dowel rod 6" long, 3/4" diameter Three screws, two washers Thin white cotton material one inch square Short piece of cotton thread Two rubber bands
Cost:	90¢

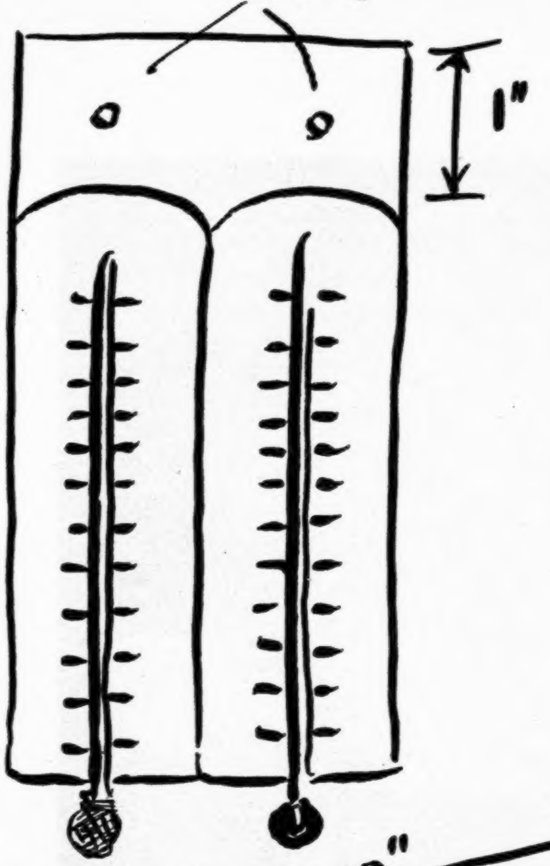

holes
1"

fig. 92

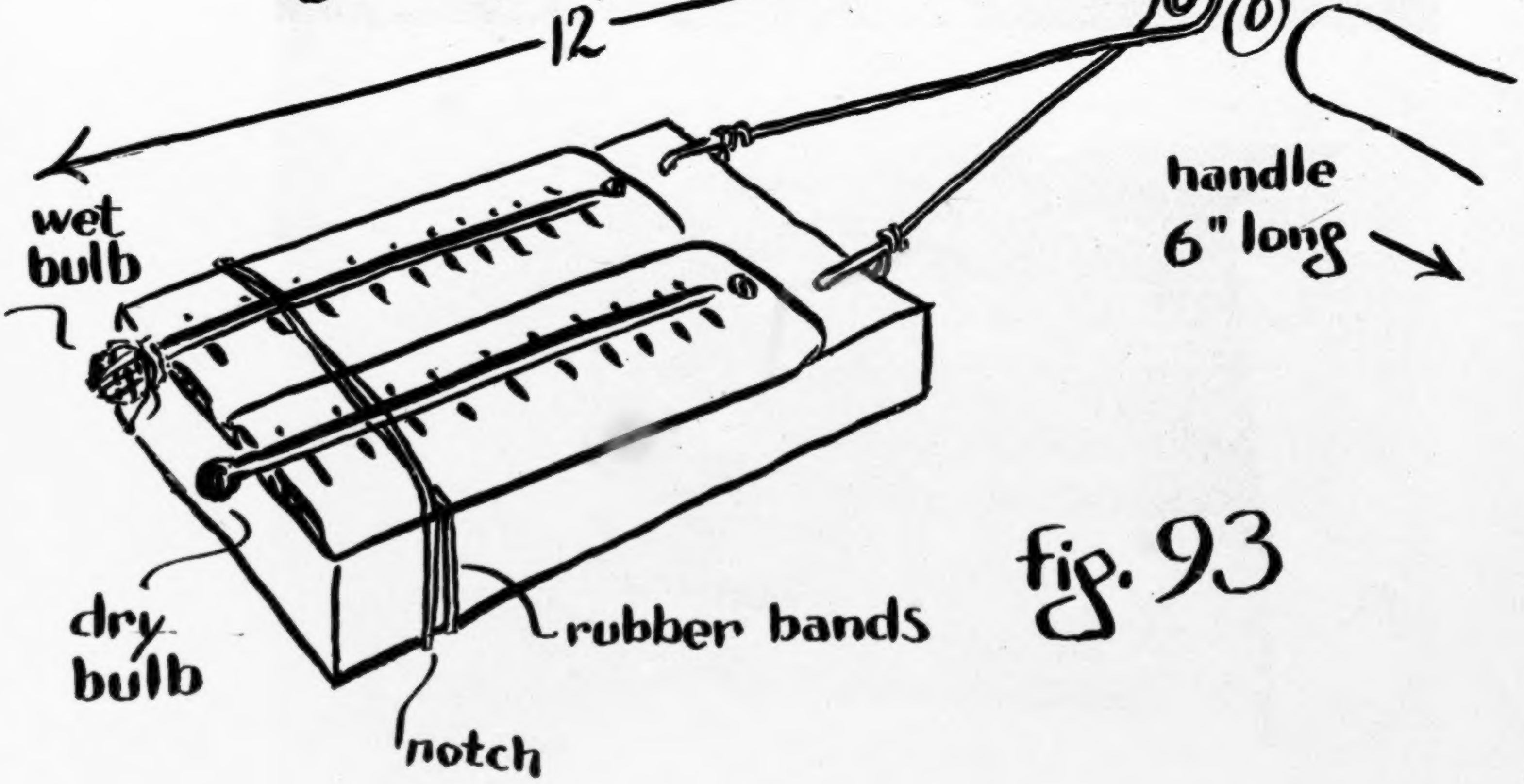

washers
12"
handle
6" long
wet bulb
dry bulb
rubber bands
notch

fig. 93

41. Measurement of Solar and Sky Radiation Intensity.

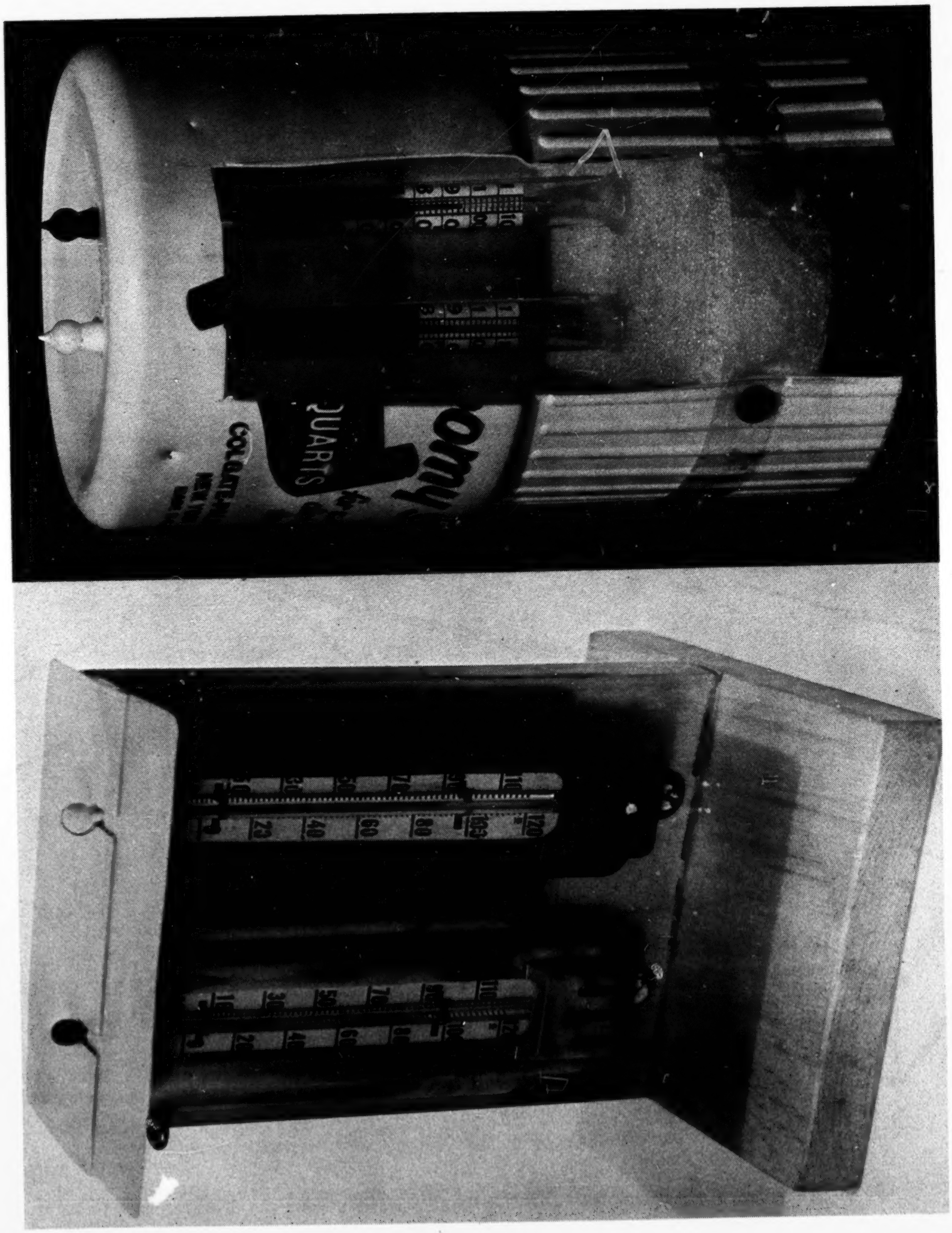


Plate 45.

Radiation from the sun reaches the earth's surface directly as solar radiation and indirectly as sky radiation. Radiation from the sky is caused by the scattering of sun's radiation by the molecules of the atmospheric gases, by the dust particles, and by clouds and fog.

Solar and sky radiation is of practical importance not only in agriculture, but also in other endeavors such as in dispatching electric power and domestic gas for cooking to various communities; on bright days the consumption of these utilities is considerably less than on dark days with heavy overcast.

All measurements of solar and sky radiation intensities depend on absorption of the radiant energy by bodies. The absorbed energy causes changes in the physical or chemical properties of these bodies, in particular, temperature changes (see Experiments 12, 13 and 14). In order to obtain a good measure of the radiation energy, the absorption must be as complete as possible, i.e., no reflection of the energy should take place. Flat black paint is a good absorber, though by no means a perfect one; soot is better, but a permanent coating of it is difficult to produce.

We can use the bulb of a thermometer directly as an absorbing body, if we make it black. Then the thermometer will indicate a temperature that is the result of the effects of absorbed radiation and of the air surrounding the thermometer. In order to eliminate the effect of the air temperature, we can use a second thermometer whose bulb we paint white, so that it reflects radiation. The difference between the black-bulb reading and the white-bulb reading is then a measure of the radiation intensity.

a) We take two identical thermometers with scales to at least 120°F and carefully saw (with fine saw blade) the material of the thermometer holder away, so that the bulb and about 1/8" of the capillary tubing is completely free. Be especially careful not to break the capillary or disturb the mounting of the capillary tubing on the scale. Then mount the thermometers upside-down on a wooden stand consisting of an upright piece of board nailed to a horizontal piece of similar size. The upright piece should be 1/2" wider than width of the two thermometers placed side by side, and as long as the overall length of the thermometers. The thermometers are mounted in such a way that the capillary tubings and bulbs stick out above the top edge of the upright board, as shown in Fig. 94.

Now we take a square sheet of white stiff paper or cardboard (better a sheet of thin flat metal which we paint white afterwards), the side length of which is the same as that of the edge A (Fig. 94) of the upright wood board. Then we cut the sheet in the middle and make in each half two slots

1/2" long and as wide at the capillary tubings; the distance B of the slots is the same as that of the mounted capillary tubings (see Fig. 95).

We then push the two half sheets from opposite sides under the thermometer bulbs, the sheet on the back side to slide over the one on the front side of the thermometers. We glue these halves together where they overlap (Fig. 96). (If metal has been used, the top side is to be painted white at this time.) Now the bulbs are painted, the left one with flat black, the right one with glossy or flat white.

b) An even more simply and quickly constructed instrument can be made from two floating fishbowl thermometers; these have the advantage that their bulbs are practically spherical, and therefore absorption is less dependent on the sun's position. However, care must be taken when selecting two thermometers out of a bin in a five-and ten cent store. Apparently these thermometers are assembled by hand and thus the extent of the scales and the total length vary. We must select two that have scales that can be read to 120°F and are of equal lengths. Furthermore, there are two types, one in which the bulbs are enclosed in the glass tube, the other in which the bulbs protrude from the glass tube; we choose the latter (Fig. 97).

One of the thermometers we dip, 1" deep, into white (preferably glossy) paint (or apply the paint with a brush), the other into flat-black paint and let them dry. In the meantime we cut about 6" of the bottom portion of a round plastic (detergent) bottle of 3 to 4" diameter; if we choose a white one, we need not paint it, otherwise we have to paint the bottom surface, which becomes the top, with white paint. Then we punch or drill two holes, 1" apart in the middle of the top; the holes should be large enough to get the thermometer bulbs through, about 1/4" will do. About 1" from the top, parallel to a line through the holes in the top, we cut a slot, 1-1/2 to 2" wide, through which we will read the thermometers (see Fig. 98). Incidentally, if we don't have a plastic bottle, we can use an empty tin can of appropriate size. Now we make a plug out of a piece of foam-plastic 1" thick, which fits snugly into the bottom of the housing. In the middle of the plug we make two hemispherical depressions, 1" apart, into which the thermometer tops fit. Instead of foam-plastic we can use wood, which, however, is not as easily shaped; the depressions have to be drilled, burned, or carved.

We assemble the instrument by inserting the thermometers from the inside of the housing upside-down through the holes in the top, so that the tips of the bulbs are about 1/2" above the housing top. Then we insert the plug into the housing until the thermometers rest in the depressions. Then we fasten the plug with four nails pushed through the housing side and put a strip of tape around the housing over the nail-heads. We turn the thermometers so that they can be easily read through the slot and cement them to the plug.

For measurements place the instrument on a level support so that the back of the thermometers points directly toward south. The measurements should be made at a place that is unshaded at all times during the day. Before the instrument is exposed for measurements it should be shaded with a piece of cardboard held over the thermometer bulbs and the white top plate, until the thermometers are indicating approximately the temperature of the ambient air. Then the shade is removed, and the temperatures are read when they have become steady. On a sunless day, the exposure may have to be several minutes in order to get a noticeable difference between the black- and white-bulb temperatures. This difference is a measure of the intensity of solar and sky radiation.

Observations should be made at least once a day around noon at the time of maximum elevation of the sun, preferably also at a fixed time during the forenoon and afternoon, according to standard time (not daylight-savings time or summer time). Other meteorological observations should be simultaneously made, especially, estimations of sky blue and cloudiness.

After sufficient observational material has become available, relationships between solar and sky radiation intensities and other meteorological variables can be studied.

Materials: a) Two identical thermometers; scales to at least 120°F
Two pieces of wood, approximately 1 x 5 x 5 inches
Flat-black and white paint
One piece of white paper or cardboard the same size as one of the pieces of wood
Glue or cement, nails or screws

Cost: $1.00

Materials: b) Two identical floating fishbowl thermometers; scales to 120°F
One round plastic bottle, 3 to 4" diameter
One piece of 1" foam plastic, about 4 x 4"
Four nails, flat-black and white paint
12" tape
Glue

Cost: 90¢

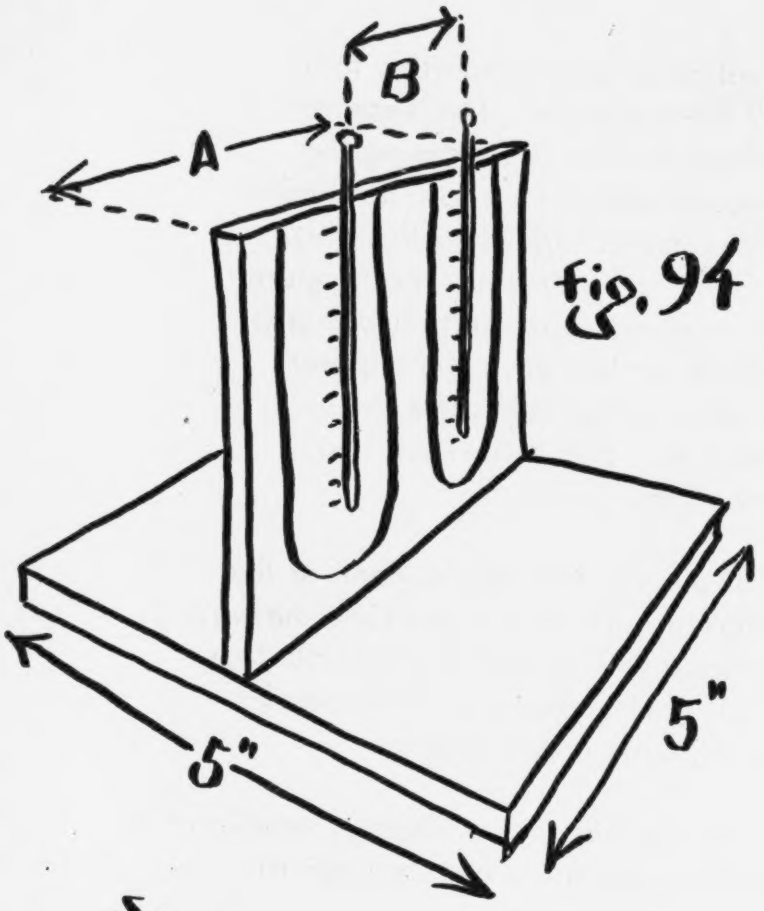


fig. 94

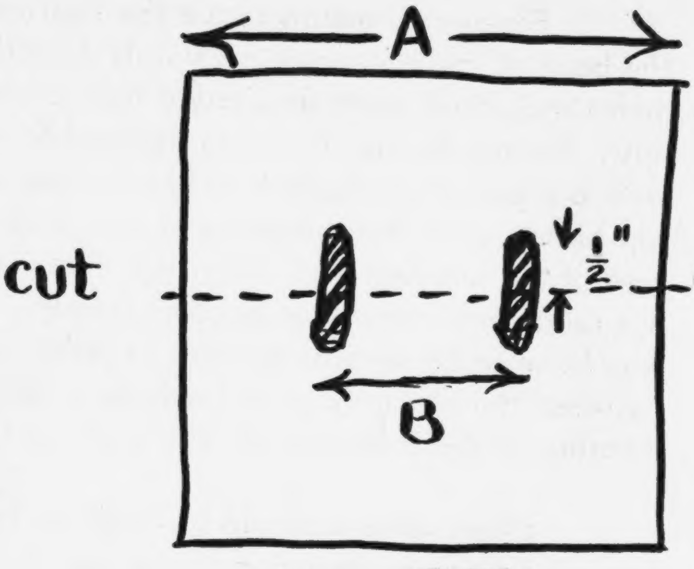

A
cut
$\frac{1}{2}$"
cut
B

fig. 95

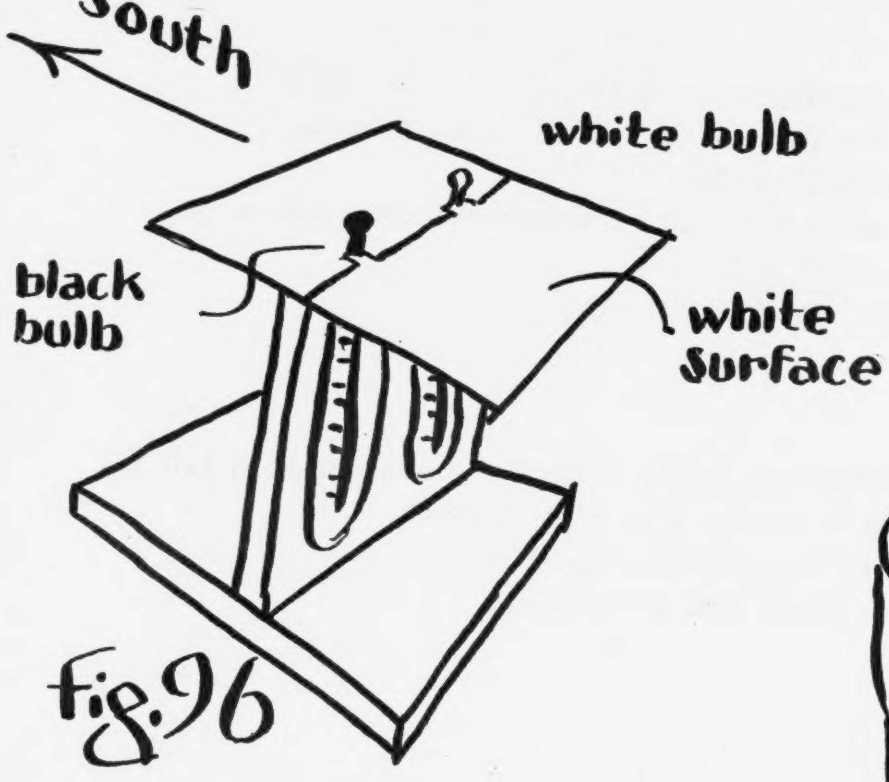

south
white bulb
black bulb
white surface

fig. 96

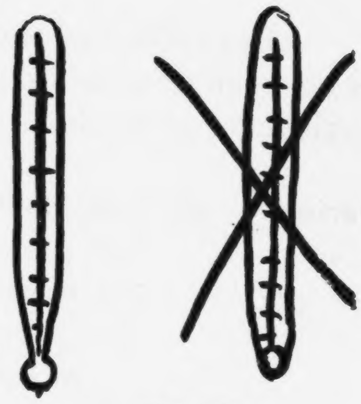


fig. 97

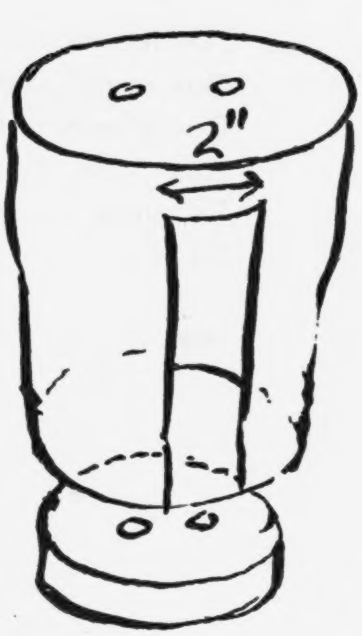


fig. 98

42. Wind Observations.

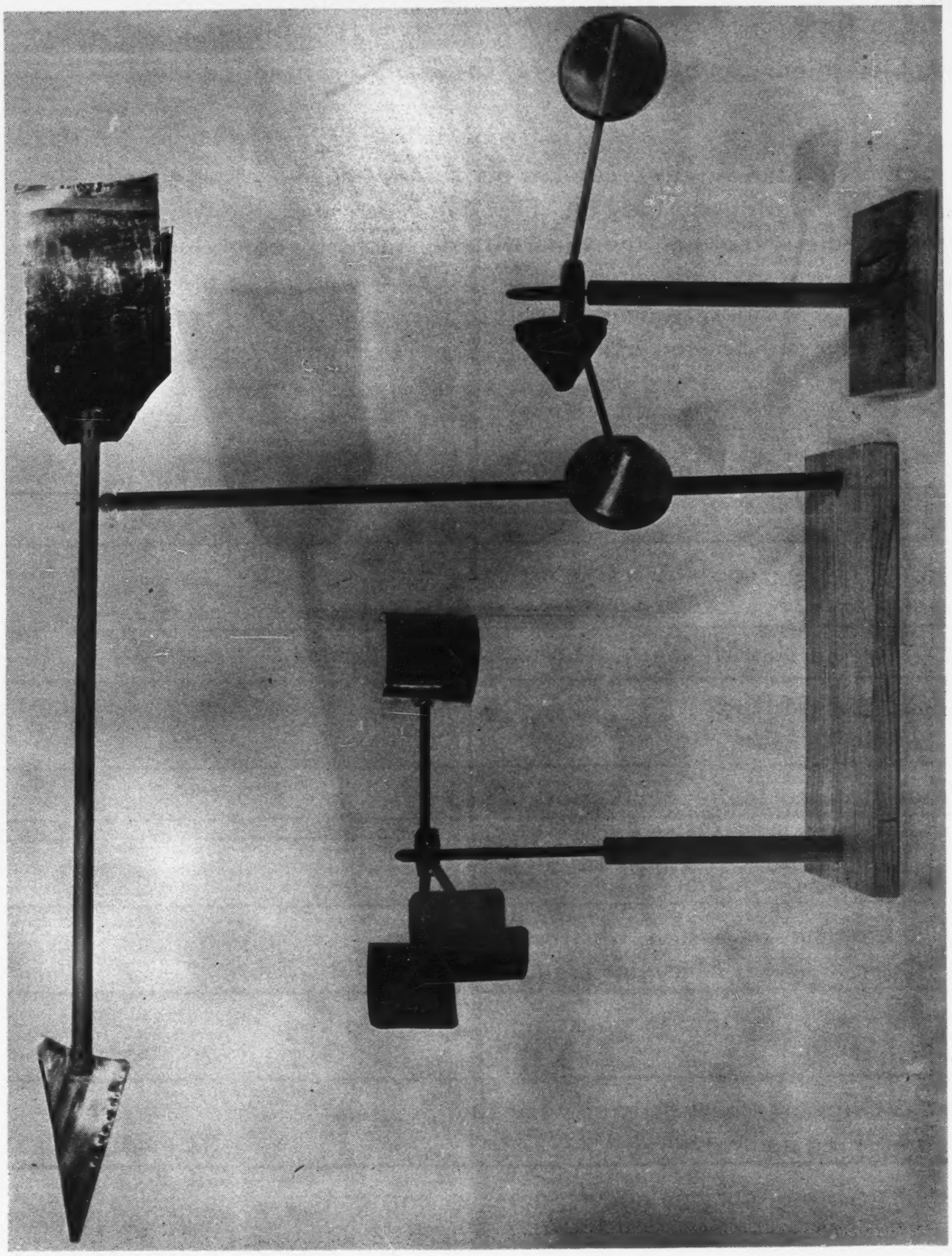


Plate 46.

Observations of wind are easy to make, but it is usually not easy to find a place at which the observed wind is representative of the larger wind field in the area. In the middle of a large field, away from obstructions to the air flow, we get more representative observations than near buildings, trees, or in streets. Where the roof of a building is safely accessible, wind observations can be made there, although this is not an ideal place.

For observing the wind we can use our senses (tactile, visual, and auditory): The wind direction, i.e. the direction from which the wind blows, can be ascertained by "feeling" the wind with our face, by observing smoke drift, flags, etc. The wind speed can be estimated according to the Beaufort scale, by which the various dynamic effects of wind can be related to its speed. Wind speed is expressed in knots (1 knot = 1.15 miles per hour).

Beaufort Wind Scale

No.	Description of Wind Effect	Equivalent in Knots
0	Smoke rises vertically	less than 1
1	Wind direction shown by smoke drift but not by wind vane	1 - 3
2	Wind felt on face; leaves rustle; vane moved by wind	4 - 6
3	Leaves and small twigs in constant motion; wind extends light flag	7 - 10
4	Raises dust and loose paper; small branches are moved	11 - 16
5	Small trees in leaf begin to sway; crested wavelets form on inland water	17 - 21
6	Large branches in motion; whistling heard in telegraph wires; umbrellas used with difficulty	22 - 27
7	Whole trees in motion; inconvenience felt in walking against wind	28 - 33
8	Breaks twigs off trees; generally impedes progress in walking against wind	34 - 40
9	Slight structural damage occurs; chimney pots and slate removed	41 - 47
10	Seldom experienced inland; trees uprooted; considerable damage occurs	48 - 55
11	Very rarely experienced; widespread damage	56 - 65
12	Hurricane force	above 65

a) To make a wind vane, we fold a sheet, 4 x 15", of metal from a wide tin can in the middle and cut out approximately as shown in Fig. 99. With a saw we make a 1" deep slot into the one end of a dowel rod, 18" long and 1/2" diameter; at the other end we make a similar slot 1/2" deep, oriented the same way as the first slot. Then we fold another sheet of tin can metal, 4-1/2 x 5", in the middle (the folded edge being 4-1/2" long) and cut out as shown in Fig. 100. This is the arrow head of the vane, which acts as a counterbalance; we insert it into the 1/2" slot of the rod, nail and glue it. The vane is similarly fastened with two nails and glue into the 1" slot (Fig. 101).

Now we fold a tin-can metal strip, 1/2 x 4" as in Fig. 102, spread the back edges of the vane apart, and fasten with liquid (or regular) solder the metal strip in the middle of the edge as shown in Fig. 101.

Balancing the shaft of the vane on a knife edge, we find the center of gravity and drill (or burn) a small hole through the rod, parallel to the folded edge of the vane. A nail that fits loosely through the shaft is hammered into a stick of wood (dowel rod) 2 ft. long, with a glass bead between the vane shaft and the stick (Fig. 101). If we wind some resin-core solder around the shaft near the arrow-head, the center of gravity is shifted closer to the shaft middle, and the vane becomes more efficient.

b) For measuring wind speed, we build a cup anemometer out of three 2-1/2" aluminum funnels. We cut the spouts of the funnels as shown in Fig. 103,so that we can fold the pointed ends over to close the funnel opening; small remaining openings are closed with liquid solder. In each of the funnels we punch two holes on opposite sides of the funnel rim which we widen so that a 3/16" dowel rod, 7" long, can barely be pushed through, until one rod end emerges from the second hole. The rod is then glued to the funnel.

As hub of the cup assembly we use a small metal lid, about 1-3/4 to 2" diameter, such as the lid of an ink bottle. We punch three equally spaced holes in the rim of the lid (for the cup spokes) and another hole in the center of the top into which we glue a metal (or plastic) pencil cap as shown in Fig. 104. Over the opening of the pencil cap we cement a small washer with a small hole through which a 3" nail should fit easily. Then we insert the cup spokes in the holes of the lid until the ends touch the pencil cap, and cement them to the cap and the underside of the lid, being careful that the faces of the funnels are parallel to the axis of the pencil cap and point in the same direction (Fig. 105). Then we paint one of the cups and its spoke with flat black paint for easier counting.

Now we drive the three inch nail, the head of which we have cut off, into the top of a stick of wood (3/4" dowel rod, e.g.), 24" long, so that the cup assembly rests on the nail without touching the stick. The nail should be filed to a sharp point.

c) For high wind speeds, it may be difficult to count the number of revolutions. For this case we can make another cup assembly in the same way, but instead of the funnels use three sheets of tin-can metal each 2-1/2 x 5" bent into half-cylinders as shown in Fig. 106. This assembly will respond only to fairly brisk winds.

For calibrating the anemometer, we must have a car. We mount the anemometer handle on a broom stick so that we can hold the instrument out of a car window well above the car roof. While the driver drives at constant speed along a straight stretch of road, the observer counts the cup revolutions per minute. Unless the calibration is made when the wind is dead calm, the procedure has to be repeated at the same speed going in the reverse direction; then the average of the two measurements is one of the calibration points. Driving in several runs at various constant speeds, such as 5, 10, 20, 30, 40 mph enables us to draw a calibration chart for the instrument with the number of revolutions per minute as abscissa and the speed in miles per hour and a second scale in knots as ordinate.

Wind observations should be made at the same time as other meteorological observations.

Material: a) Sheet of tin-can metal, 4 x 15"
Sheet of tin-can metal, 4-1/2 x 5"
Strip of tin-can metal 1/2 x 4"
One 1/2" dowel rod 18" long
One stick of wood 24" long
Glue, nails, one glass bead

b) Three aluminum funnels 2-1/2" wide
Three 3/16" dowel rods, 7" long
One metal (or plastic) pencils cap
One metal lid 1-3/4 to 2" diameter (such as from ink bottle)
One 3" nail
One small metal washer, 3/8" diameter
One stick of wood 24" long (3/4" dowel rod)
Glue, flat-black paint

c) Three pieces of tin-can metal, 2-1/2 x 5"
Three 3/16" dowel rods, 7" long
One metal (or plastic) pencil cap
One metal lid, 1-3/4 to 2" diameter
One small washer, 3/8" diameter
Glue, flat-black paint

Cost: 90¢

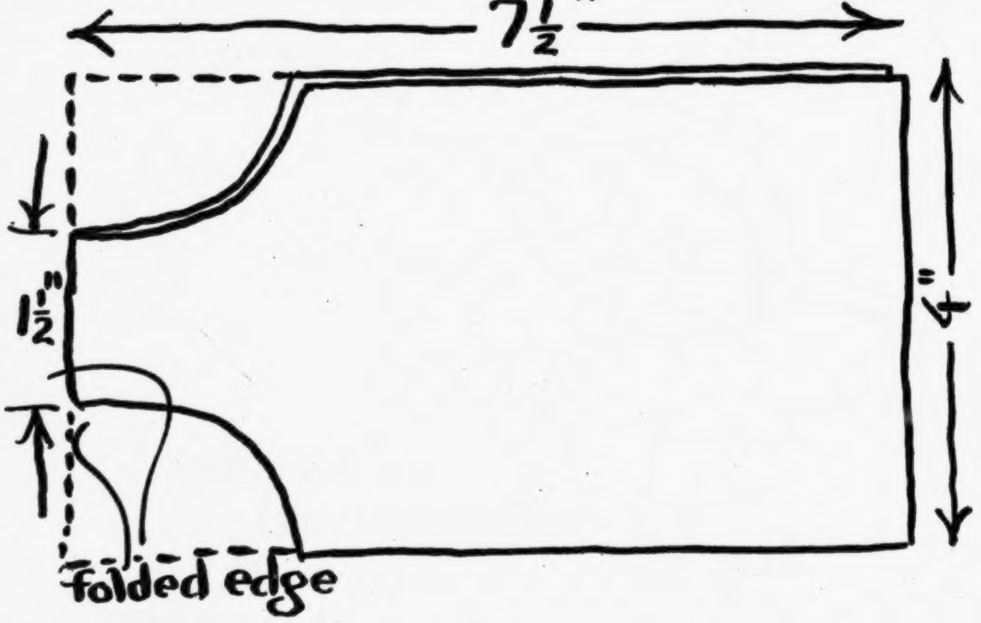

7½"
1½"
4"
folded edge

fig. 99

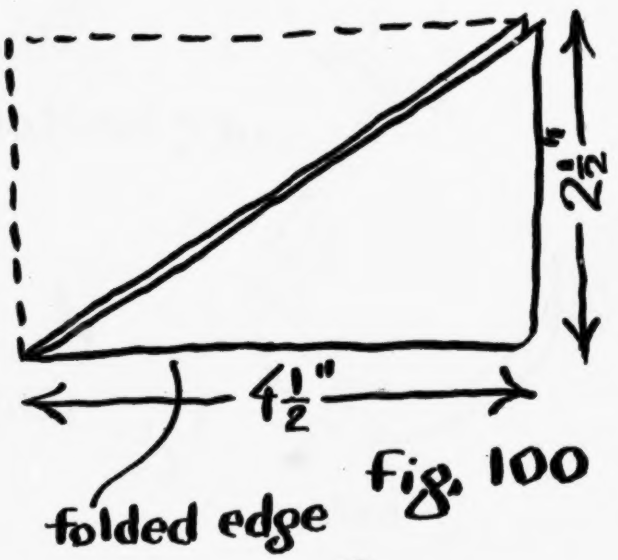

2½"
4½"
folded edge

fig. 100

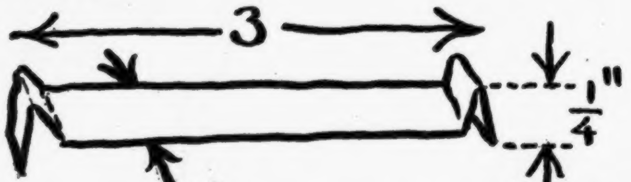


fig. 102

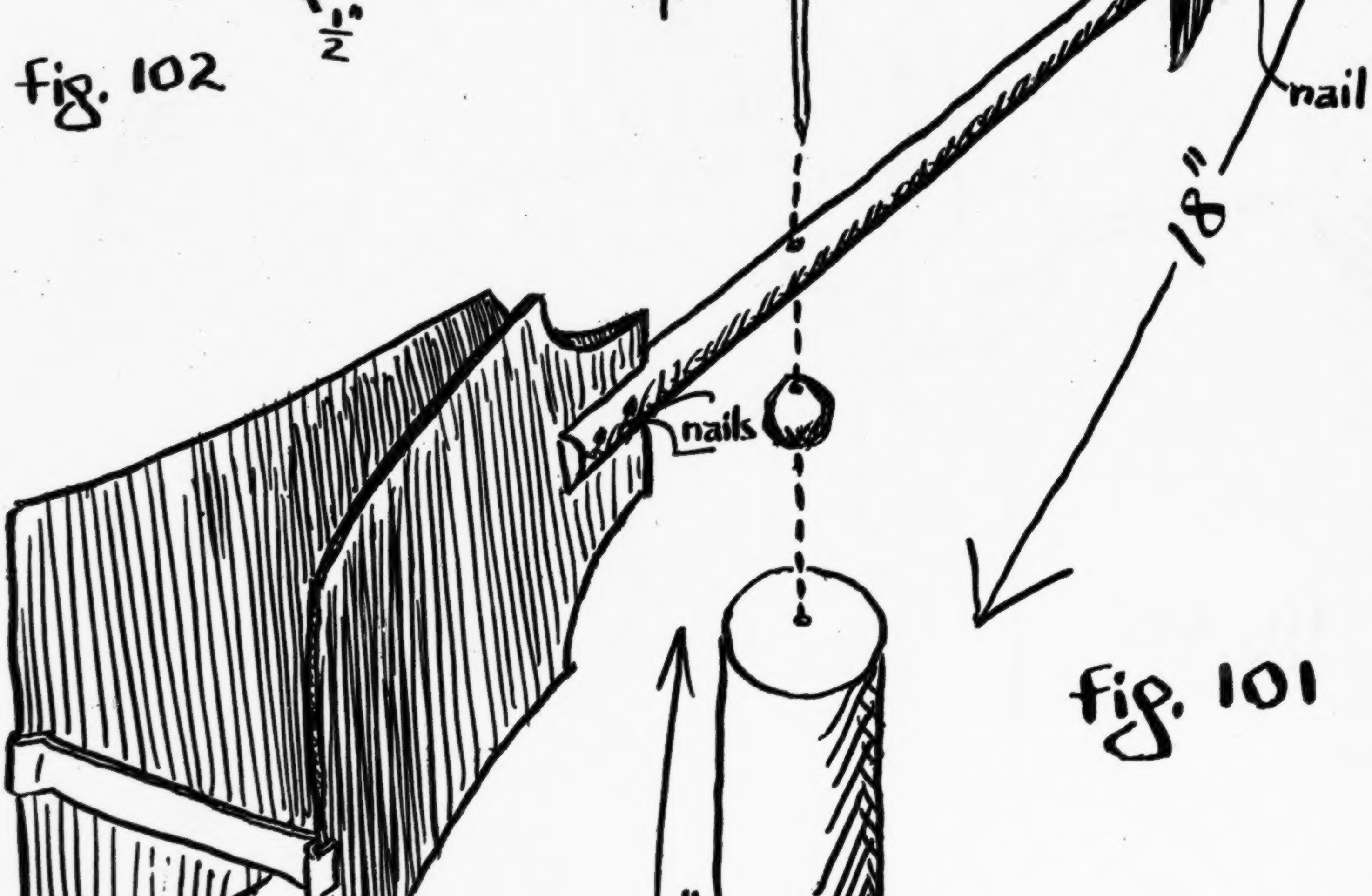

nail
18"
nails
24"

fig. 101

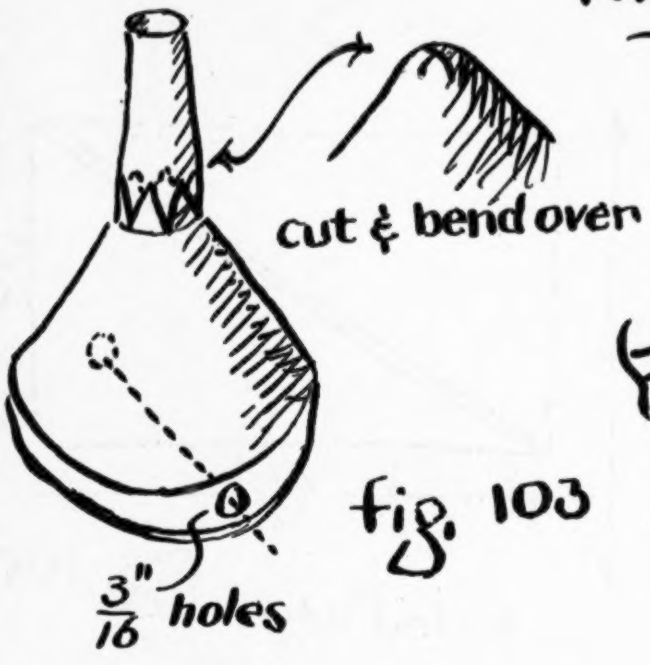

cut & bend over
3/16" holes

fig. 103

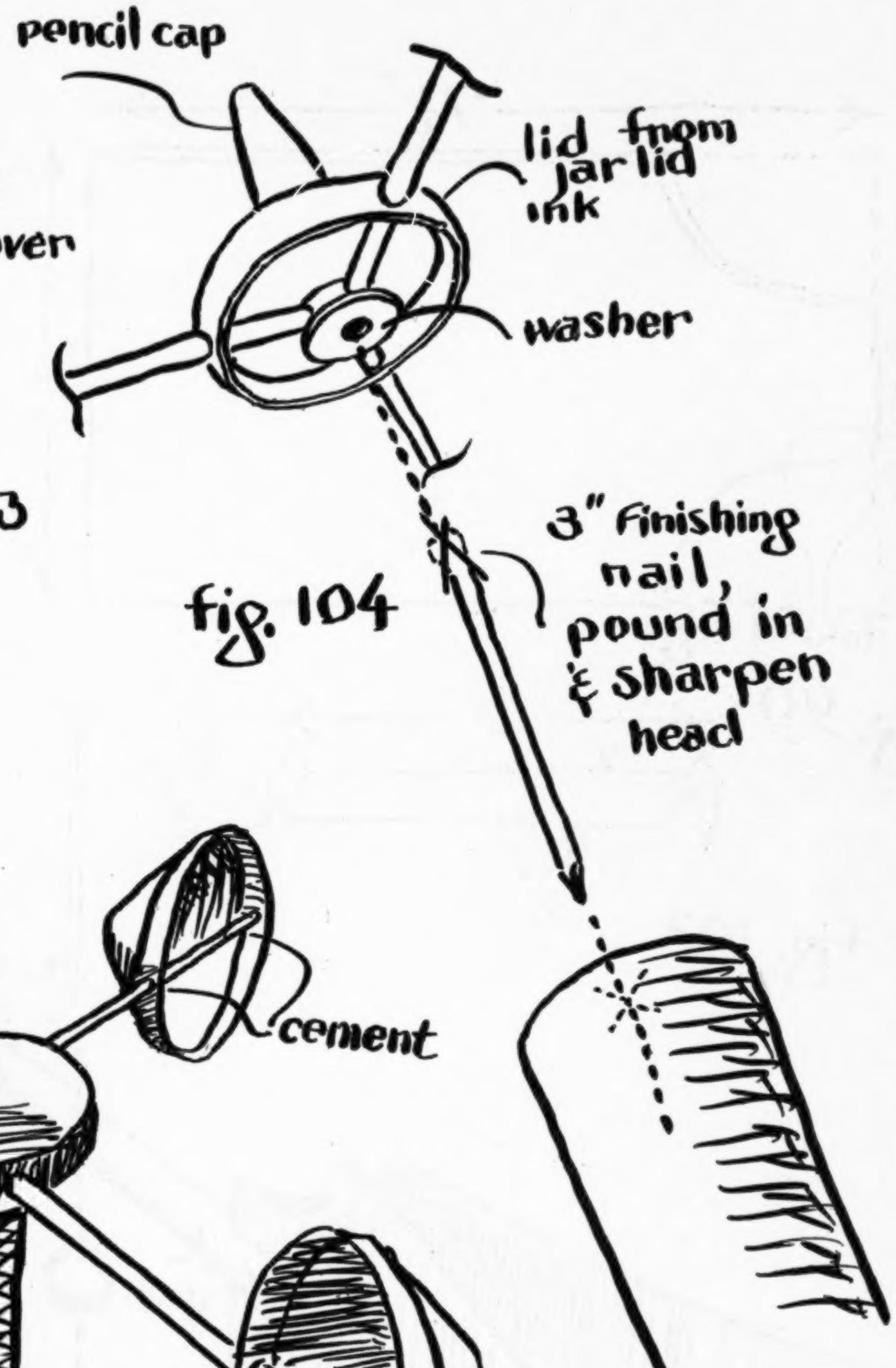

pencil cap
lid from
jar lid
ink
washer
3" finishing
nail,
pound in
& sharpen
head

fig. 104

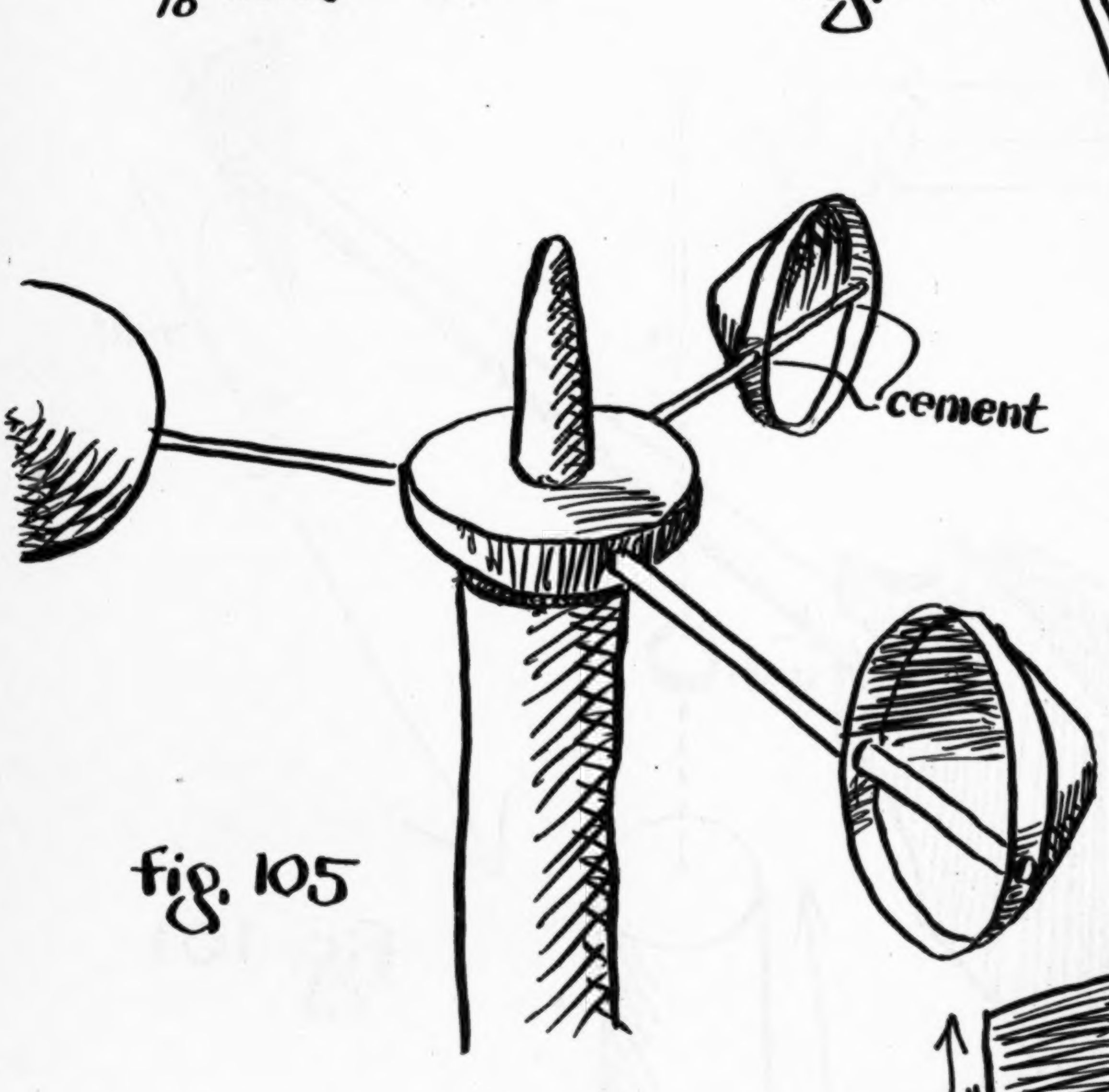


fig. 105

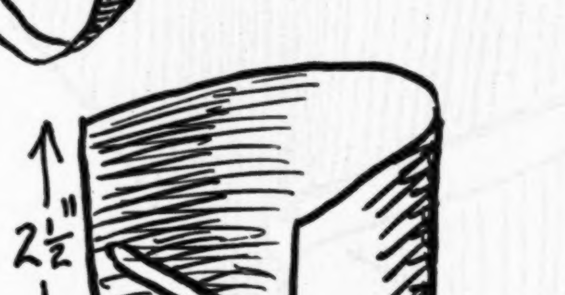


fig. 106

43. Pressure-Change Measurements.

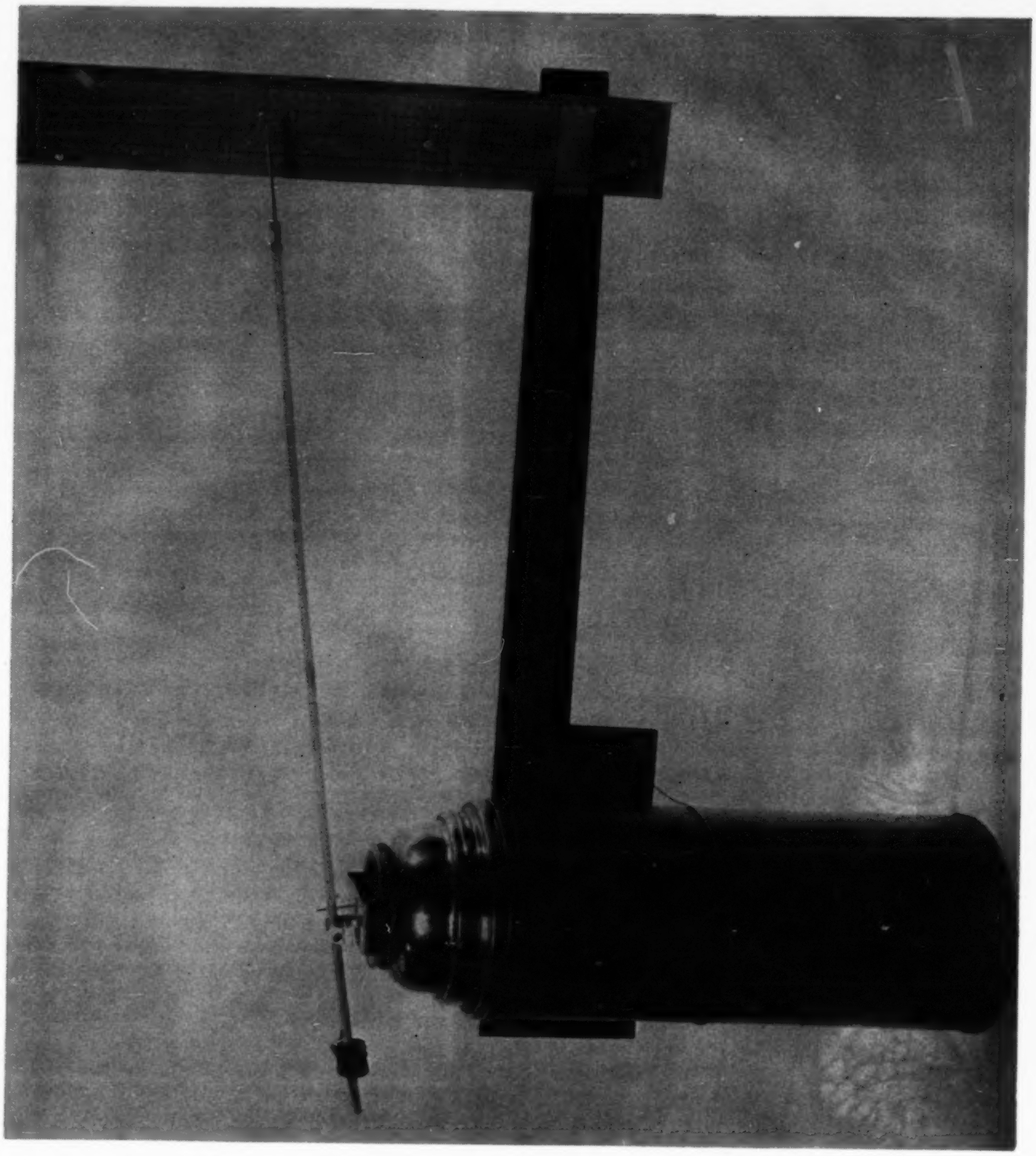


Plate 47.

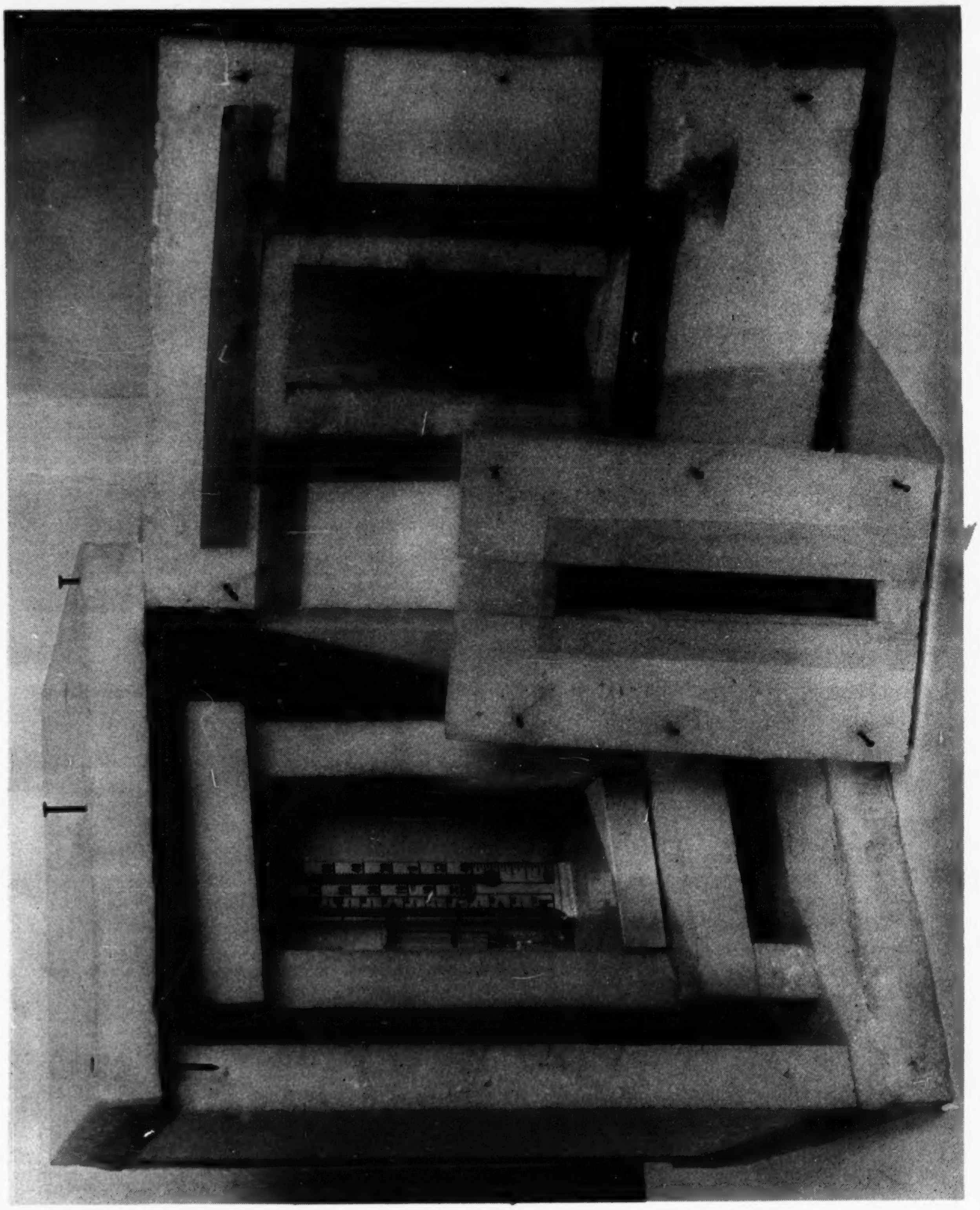


Plate 48.

An instrument with which pressure changes can be measured is called a variometer. A Cape-Cod barometer is a variometer, rather than a barometer. As was demonstrated in Experiment 30, such variometers are not only responsive to pressure changes, but also to temperature changes. Only if we keep a variometer in an environment of constant temperature, does the instrument indicate pressure changes reliably. It is ordinarily very difficult to find such an environment; if the temperature of an enclosed volume of air is known together with dimensional quantities of the appartus, the indicated changes can be corrected for the portion of the changes caused by temperature variation.

a) A simple, although by no means ideal, solution is the use of a thermosbottle as container of the enclosed volume of air; temperature variations in a thermosbottle are reduced, though not eliminated. To construct a variometer, we proceed as follows.

We remove the glass container of an ordinary quart-thermosbottle (mouth diameter about 1-1/2"), wet the rim, and stretch a rubber membrane (pice of a toy balloon) over it, which we fasten tightly with a stretched rubber band. Then we return .the bottle to its metal or plastic container. We then cut a strip of metal (from a tin can or other source) 1" wide and several inches long (depending on the configuration of the top portion of the container) and bend it over the top of the thermosbottle as shown in Fig. 107, cutting off the excess of the strip ends. In the middle of the top of the strip we make a "T" shaped incision 1/4" deep and 1" across the top as in Fig. 108; we also punch out an oval hole, leaving enough metal between the top of the "T" and the opposite edge not to weaken the strip too much. We punch two pin holes in the middle of each side of the "T" and bend at right angles upward as shown in Fig. 109.

We now glue or tape two thin drinking straws together to make one about 16" long. Into one end we glue a tooth pick, into the other end a 4" piece of 1/8" dowel rod (Fig. 110). We stick a pin with glass head 3-3/4" from the end through the dowel rod so that it sits fast. Another such pin is pushed through the dowel rod at right angles to the first pin, 3/8" away from it toward the end. The second pin is withdrawn and the pointer mounted to the metal strip as shown in Fig. 111. A counter weight (nut, wire spiral, etc.) is fastened to the short end of the pointer so that the long end is only a trifle heavier than the short end.

A strip of smooth aluminum foil, 1/4" wide, is layed over the middle of the rubber membrane and taped to the rim of the thermosbottle container. The pointer assembly is put on top of the thermosbottle so that the pin, which sticks head down through the oval hole in the metal strip, rests on the aluminum strip (to diminish friction) in the middle of the membrane; the pointer should be parallel to the aluminum strip. The pin is pushed up or down through the dowel rod, so that the pointer is directed upwards at an angle of 10 to 20° from the horizontal. The sides of the metal strip are held to the bottle top by means of tightly fitting rubber bands.

We make a scale on a strip of white cardboard, 2 x 12" and glue it to the end of a strip of masonite or thin plywood, about 2 x 18", as shown in Fig. 112. The other end of the masonite strip is fastened securely to the thermosbottle near the top with a piece of stiff wire, 30" long. The end of the pointer should be approximately in the middle of the scale, very close to it without touching it (Plate 47).

To eliminate temperature fluctuations as much as possible, the variometer should be placed in a corner of the basement of a building, preferably one without windows, heating pipes, etc. If such a place is not available, the variometer should be placed into the middle of a large cardboard box with cover, filled with insulating material such as excelsior, glass wool, or foam plastic. Care should be taken that the top of the instrument, the pointer, and scale are completely free. A window is cut into the side of the box through the insulating material and the opening is covered with a sheet of glass or plastic, so that we can read the position of the pointer on the scale from the outside, without having to open the box.

Readings of the variometer, distinguishing between pressure rises and pressure falls, should be taken at the same time as other meteorological observations. Which way does the pointer move, when the pressure rises? When it falls? Why?

b) Another version of a variometer of the Cape-Cod type with correction for temperature changes is made as follows. We make a small stand of a piece of wood 3/4 x 2-1/2 x 3" to which we glue another piece 3/8 x 1 x 7-1/4" as shown in Fig. 113. To the upright piece we screw a millimeter scale (or inch scale with 1/16" divisions) of about 15 cm (6in.) length so that the markings are on the left side, and on the right side we fasten (with the same two screws) a thermometer. It is best to use a thermometer with a plastic frame, from which we can easily separate the thermometer with its metal scale; the sides of the metal scale can be trimmed so that the width of the thermometer is not more than 5/8" (Fig. 114). Then we drill six or seven very small holes through the scale and the wood behind it, about 1/4" from the left edge, about every two centimeters (3/4") starting near the bottom.

We remove the rubber bulb from a glass eyedropper and carefully grind the wide end of the glass tube on fine sandpaper to a flat edge as shown enlarged in Fig. 115. To the narrow end of the eyedropper we fasten a 6" length of plastic tubing which has an inner diameter of 1/16" and an outer diameter of 1/8" (gas line for model engines). We cut a small disk, to cover the top of the glass tube, either from heavy plastic (tooth-paste tube cap, for example), or from thin metal; this cover will later be cemented airtight to the ground end of the glass tube, so it should be flat which we can achieve by grinding on fine sandpaper. Now we hold the glass tube and the plastic tubing, bent sharply upwards, between several layers of paper or cloth, or with gloves, so as to avoid warming the instrument; we fill some thin salad or machine oil, preferably oil that is colored for better visibility, into the glass tube (this can be best done with another eyedropper), so that the oil level in the tube is 1-3/4" from the top (Fig. 116). We then cement the cover airtight on top of the glass tube and mount with very thin wire (or stout thread) the glass tube to the side of the scale and the plastic tubing directly on the scale, as shown in Fig. 117.

We let the instrument sit for an hour and then take a reading of the oil level in the tubing on the scale and a reading of the temperature. Then we move the instrument to a warmer place and take readings again after ten minutes. We then find a colder place (basement in summer, outdoors in winter) and take readings again after 10 minutes. The readings are preferably taken, when the temperature has become constant. To obtain more calibration points, we can place the instrument into a large tin can with tightly fitting cover, which we immerse in a large bucket with hot water, making sure that no water can get into the can. The water should be slowly stirred to assure fairly uniform water temperature. Every five minutes or so, we take quick readings of scale and temperature. When the temperature is down to room temperature, we fill the bucket with very cold water and obtain a series of readings at relatively low temperatures.

We then plot the scale readings as ordinate, the temperatures as abscissa on graph paper and draw the best fitting curve through the observed points. We select a "standard" room temperature - say - 70°F, and take from the curve the corresponding scale reading. Then we also read from the curve the scale readings for lower and higher temperatures at 5° intervals, viz. 65°, 60°, etc., and 75°, 80° etc. The differences of the scale reading at 70°F minus those at the other temperatures represent the temperature corrections (with the respective + and - signs), that must be applied to all subsequent observations. Thus, when a reading was taken at a temperature lower than 70°, we add the correction to the reading, whereas when it was taken at a temperature higher than 70°, we subtract the correction from the reading. Of course, at 70° the correction is zero by definition. We make another graph of the corrections as ordinate and temperatures as abscissa, which we use for our observations.

The changes of temperature-corrected readings from one observation to the next indicate the net pressure changes that have occurred in that period of time. Assuming that the numbering of the scale on the instrument increases from the bottom to the top, an increase in corrected scale reading since the last observation indicates falling pressure, a decrease in reading indicates rising pressure.

c) In spite of this possibility for correcting the temperature effect, the thermal lag of the thermometer and of the instrument are different. For this reason it is advisable to enclose this instrument in a small box out of sheets of foam plastic (as used for building insulation) with a double window in the front through which we can read the instrument without having to open the box. For additional thermal insulation it is good to make a second, larger box around the smaller one with an air space of one inch between the inner box and the outer one, the outer one having again a double window in the front. The double window can be made of transparent plastic sheets, one taped to the outside of the front panel, the other one to the inside (Plate 48).

Materials: a) One thermosbottle, quart size
One strip of metal 1 x 5"
Two thin drinking straws
One tooth pick
One 1/8" dowel rod, 4" long
Rubber bands
One toy rubber balloon
Two stick pins with glass heads
One strip of aluminum foil 1/4 x 2"
30" of stiff wire
One strip of masonite or thin plywood, 2 x 18"
One strip of white cardboard 2 x 12"
Glue

Cost; $2.50

b) One thermometer
One eyedropper (glass)
6" plastic tubing, 1/16" inner diameter (model engine gas line)
One millimeter scale, 15 cm long
One piece of wood 3/4 x 2-1/2 x 3"
One piece of wood 3/8 x 1 x 7-1/4"
Two small bolts with nuts, or screws
2 ft. of very thin wire
Salad or machine oil (very thin)
A 1/2" square of metal or thick plastic
A large tin can with tight cover, into which the instrument fits
A large bucket with hot water
Two sheets of graph paper

Cost: 70¢

c) For insulation box of variometer b) one length of foam plastic sheet, 1" x 12" x 120"

Cost: $2.00

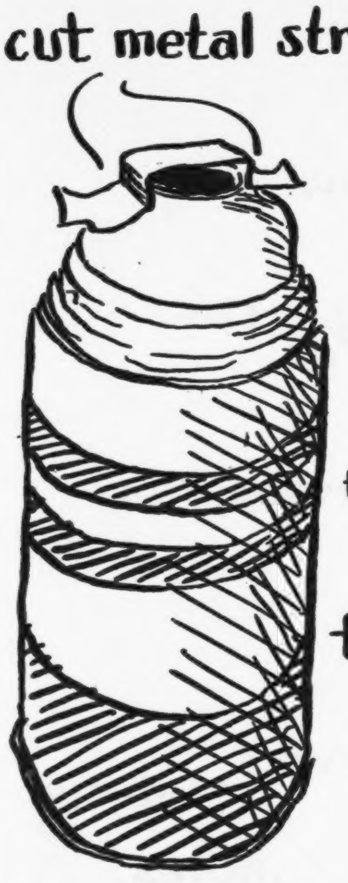

cut metal strip here
thermos bottle

fig. 107

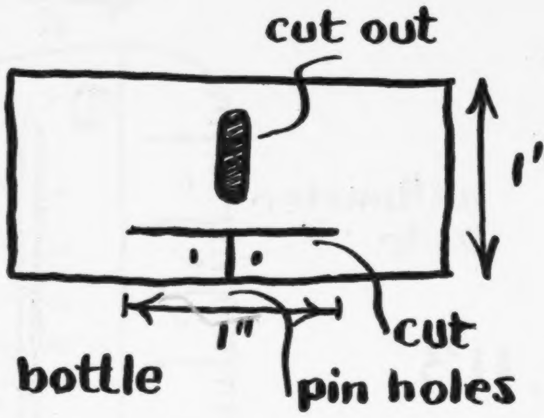

cut out
1"
1"
cut
pin holes

fig. 108

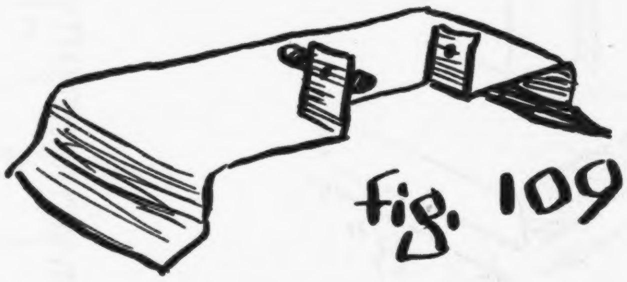


fig. 109

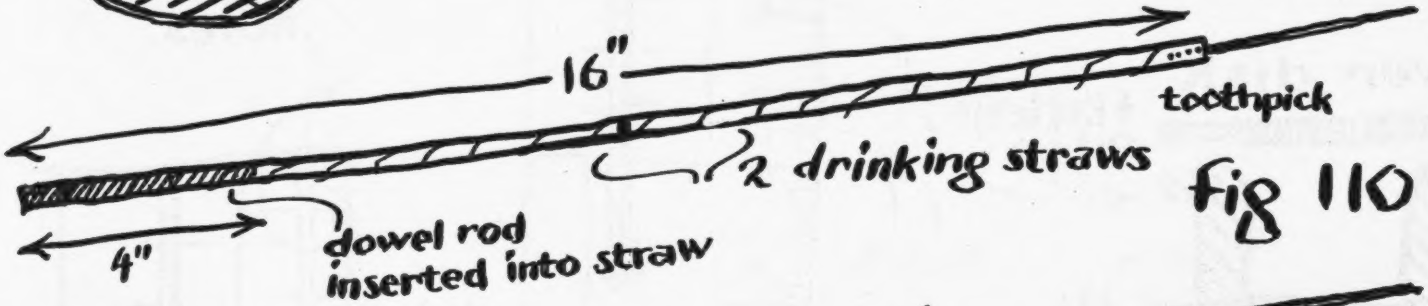

16"
toothpick
2 drinking straws
4"
dowel rod inserted into straw

fig 110

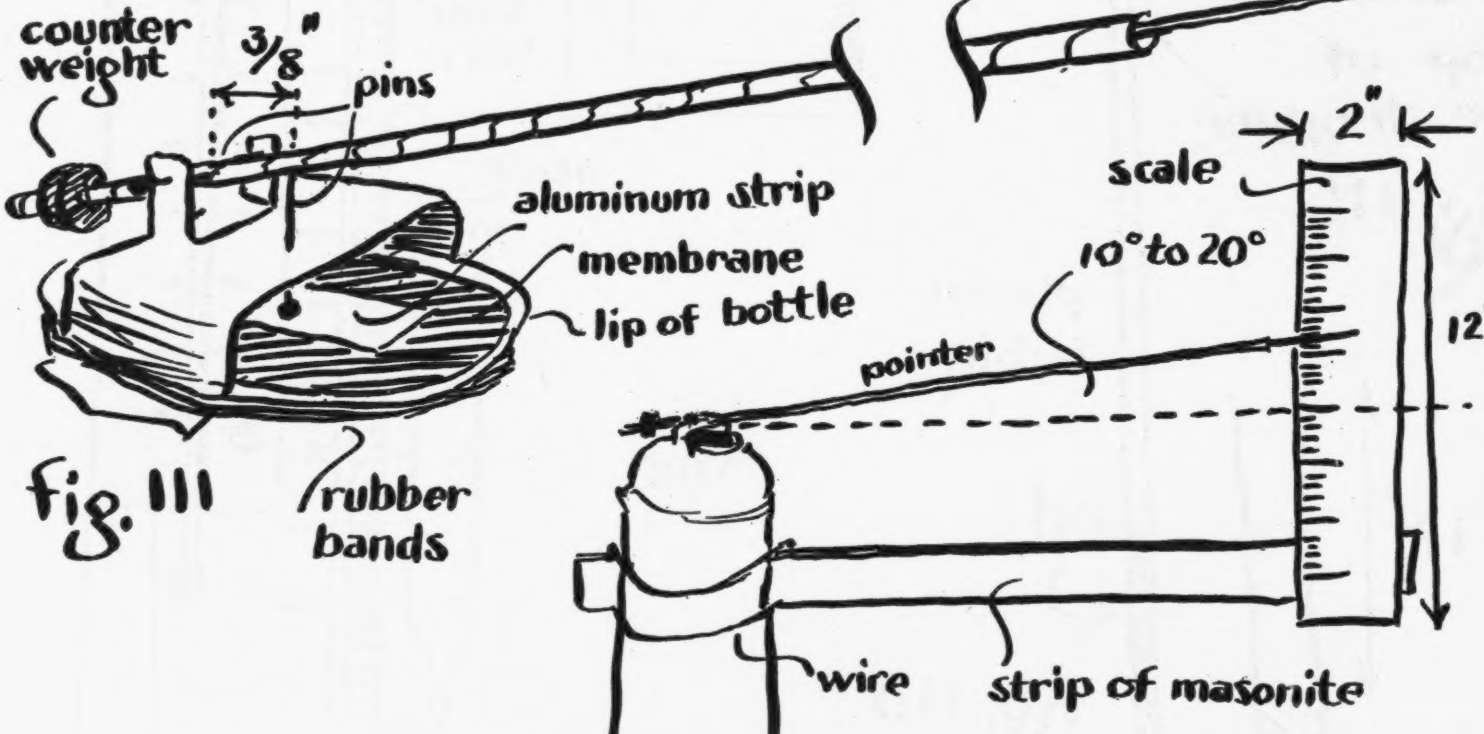

counter weight
3/8"
pins
aluminum strip
membrane
lip of bottle
rubber bands
2"
scale
10° to 20°
12"
pointer
wire
strip of masonite
18"

fig. 111

fig. 112

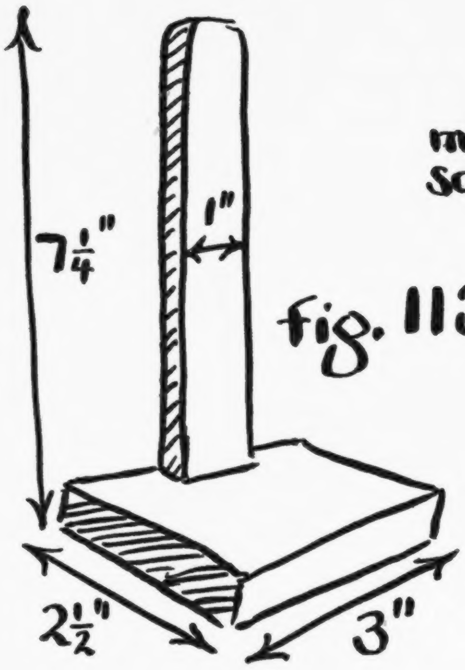


fig. 113

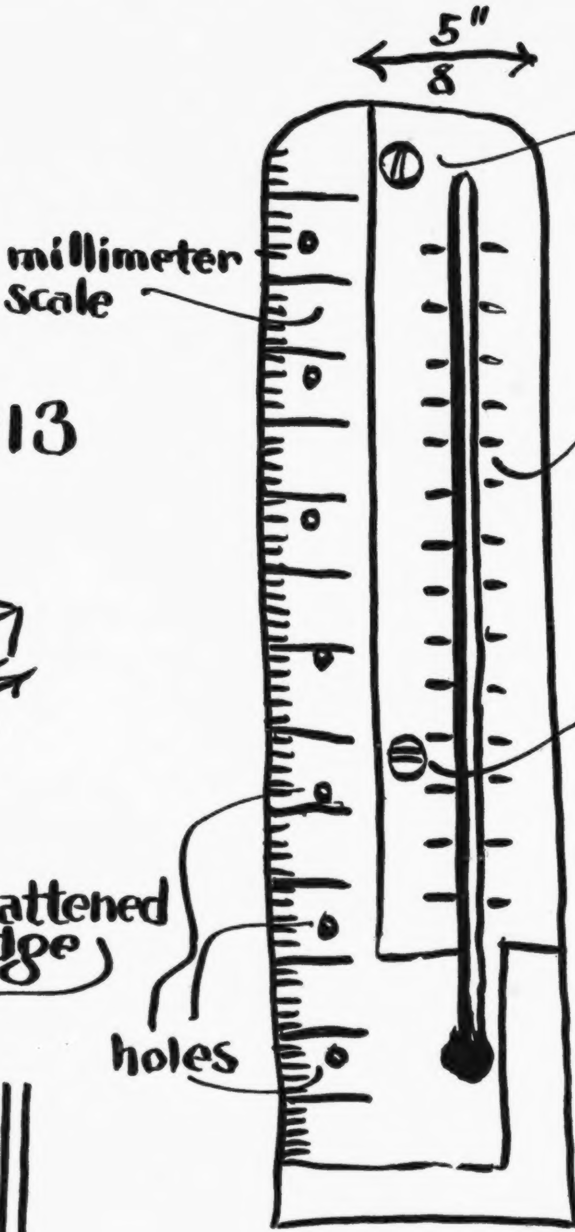

5"/8
screw
millimeter scale
thermometer
screw
holes

fig. 114

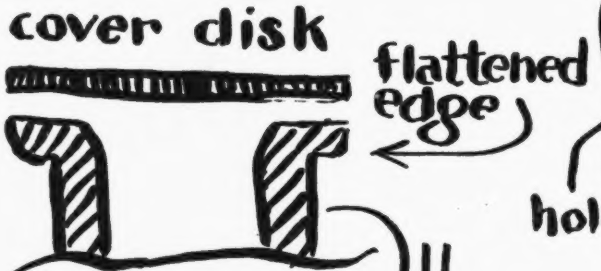

cover disk
flattened edge
top of eye dropper

fig. 115

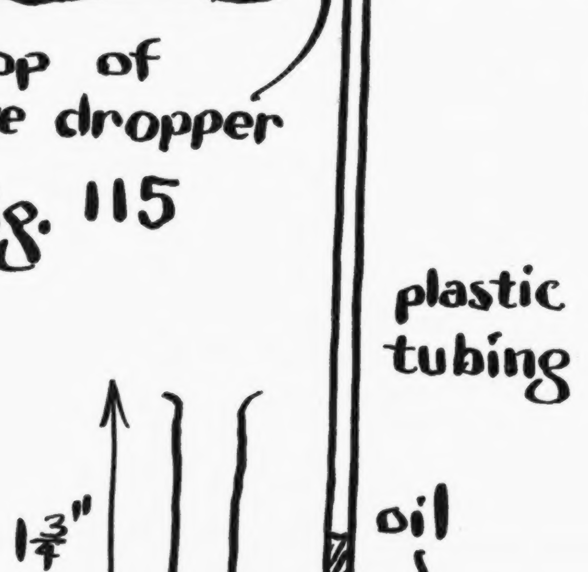

plastic tubing
1¾"
oil

fig. 116

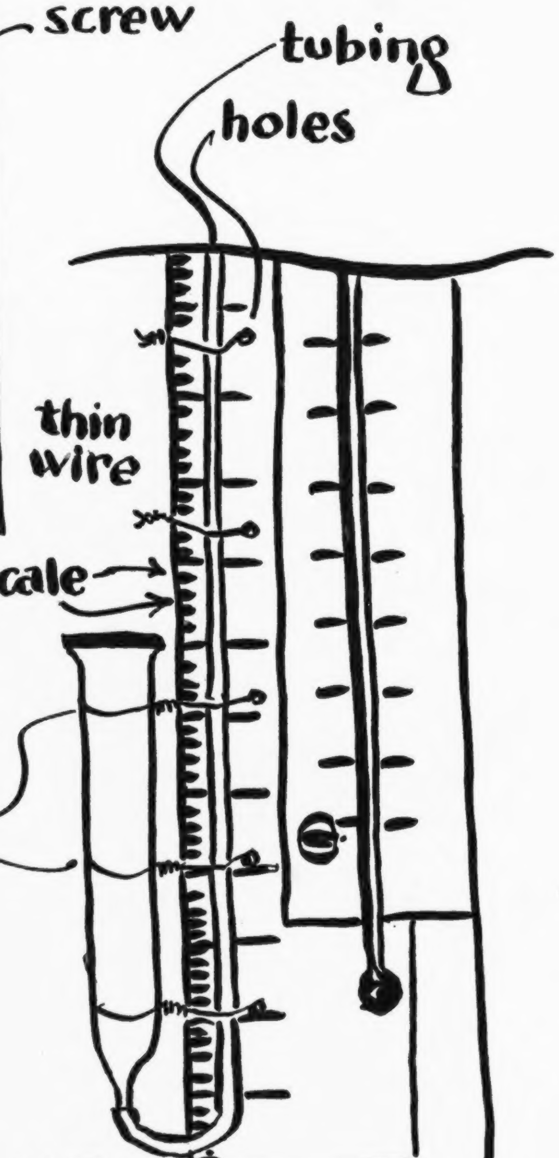

tubing
holes
thin wire
scale
thin wire

fig. 117

44. Rain Measurements.

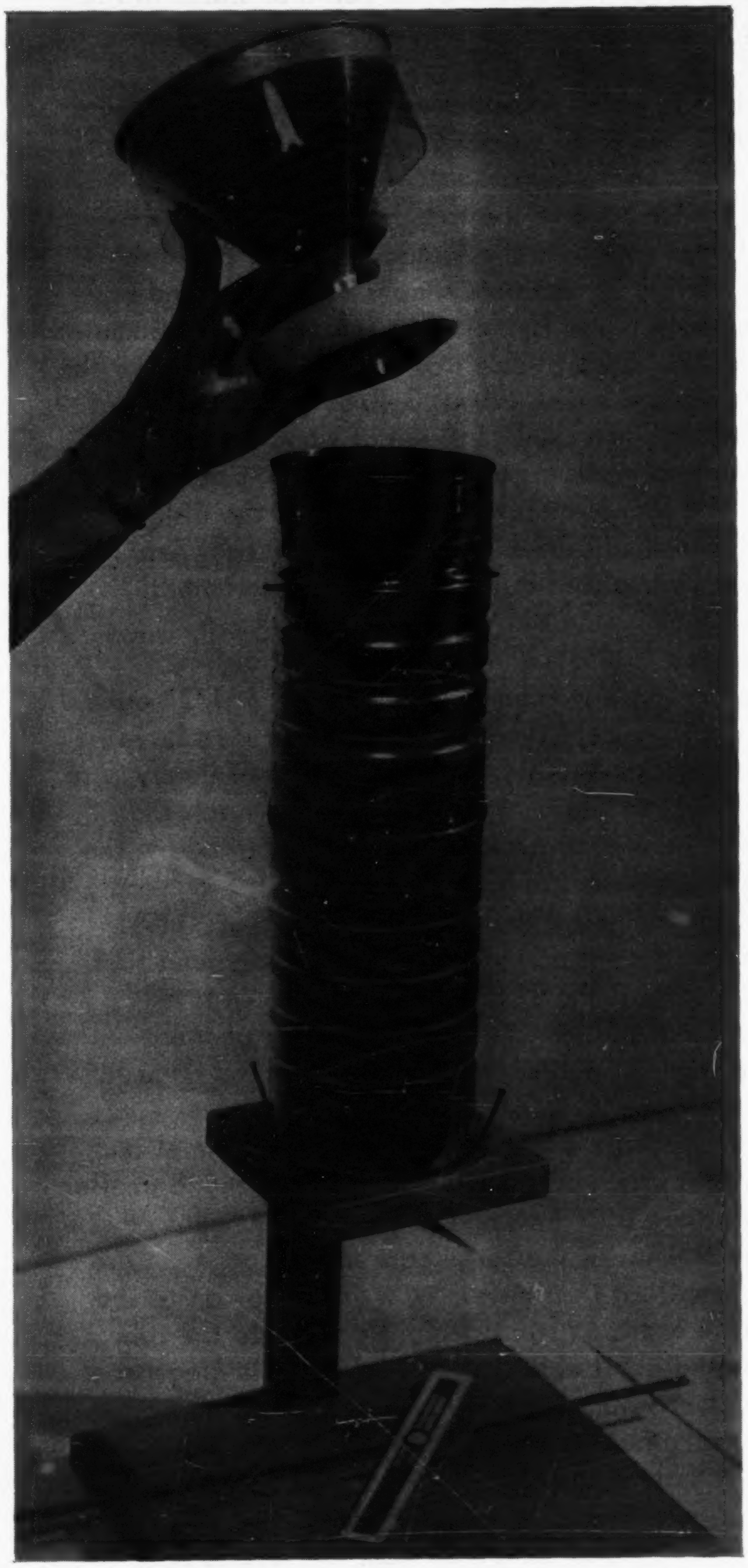


Plate 49.

The amount of rain is measured as the depth of water on level, impermeable ground. In principle, any cylindrical can, properly exposed, can be used to catch precipitation; for measuring the depth of water in the can, we use a ruler. However, it is desirable to measure precipitation accurate to 1/100", so that it is necessary to magnify the depth of the catch. Moreover, evaporation of water from the open can prior to measurement must be minimized; this is achieved by placing a funnel over the can.

From two large tin cans we remove the tops, from one of them also the bottom, and fasten the latter on top of the former by means of liquid solder (or hot solder, if available). These cans should be 7" high and have 4-1/8" inner diameter. We buy a metal funnel of at least 5" inner diameter (a standard size seem to be 5-3/8") and place it on the can. To prevent the funnel from being blown off we saw a disk (about 3-7/8" diameter) out of wood, that should fit smoothly into the can. Instead of wood we can use foam-plastic which can be worked much more easily. A hole is bored through the disk's center for the funnel neck (Fig. 118), and the disk is cemented to the funnel. Also to avoid driving rain getting in between the funnel and the can, we cement a shield of plastic or tin-can metal, 2 x 15", to the rim of the funnel.

The rain gage is attached to a wooden post (about 1 x 1-1/2" cross section, 3 to 4 ft. long) which is to be driven into the ground. To have the gage removable for taking measurements, we fasten a ring of heavy wire (clothes hanger), 18" long, near the top of the post, through which the gage fits easily. The can rests on a platform, 5 x 5", about 11" below the ring; four nails in the platform keep the can in a fixed position. The top of the post should be several inches below the top of the can (Fig. 119). The rim of funnel and can must be level and so high above the ground that no rainwater can splash into it. Also the distance of the gage from all higher objects around it must be at least as great as the height of these objects above the gage. No wires or cables should hang over the gage.

For measuring the precipitation amount, we remove the funnel and pour the contents of the can into another cylindrical tin can of much smaller diameter, preferably not more than 2". Two or three such small cans can be soldered together in the same manner as the large cans for the gage. Care must be taken that no water is spilled in transferring it from the can to the measuring tube. Then we put a redwood stick straight down into the tube until it touches bottom and withdraw it again; the water level is clearly visible on the wood. The stick should be straight and very thin, about 3/16 x 1/8" in cross section, as otherwise too much water is displaced. With a ruler we measure the length of the water mark on the stick.

The depth of precipitation, P, is computed from the relationship

$$P = L\ (d/D)^2,$$

where L is the length of the water mark, d is the inner diameter of the measuring tube, D is the inner diameter of the funnel. For example, let the funnel diameter be D = 5-3/8", the measuring-tube diameter d=1-1/8"; the factor $(d/D)^2$ is approximately 0.044. So if the length of the water mark was 1-3/16" = 1.19", the precipitation amount P = 1.19 x 0.44=0.05 inch. To facilitate precipitation computations, we can make a conversion diagram on graph paper with L as abscissa and P as ordinate.

When precipitation occurred in an amount too small to be measured, it is recorded as "trace". Precipitation traces, that occur between observations, can be automatically registered, by means of a piece of stiff paper or cardboard, about 2 x 2", over whose surface indelible pencil has been rubbed; even tiny drizzle droplets make noticeable spots. The paper is best fastened with thumbtacks to a block of wood set on the ground near, but not under, the raingage. Rain measurements are made once daily at the same time as other meteorological observations, preferably in the morning.

Material:
Two large tin cans, 7" high, 4-1/8" diameter
One metal funnel about 5" diameter
One wooden post, 1 x 1-1/2" cross section, 3 to 4 ft. long
One piece of wood 5 x 5" x 3/4"
One piece of wood or foam plastic, 1 x 4 x 4"
One strip of sheet metal or plastic, 2 x 15"
One 18" piece of stiff wire
One redwood stick, 1/8 x 3/16 x 12"
Two or three tin cans of small diameter
Nails, cement, glue, liquid solder
Indelible pencil and white cardboard

Cost: 60¢

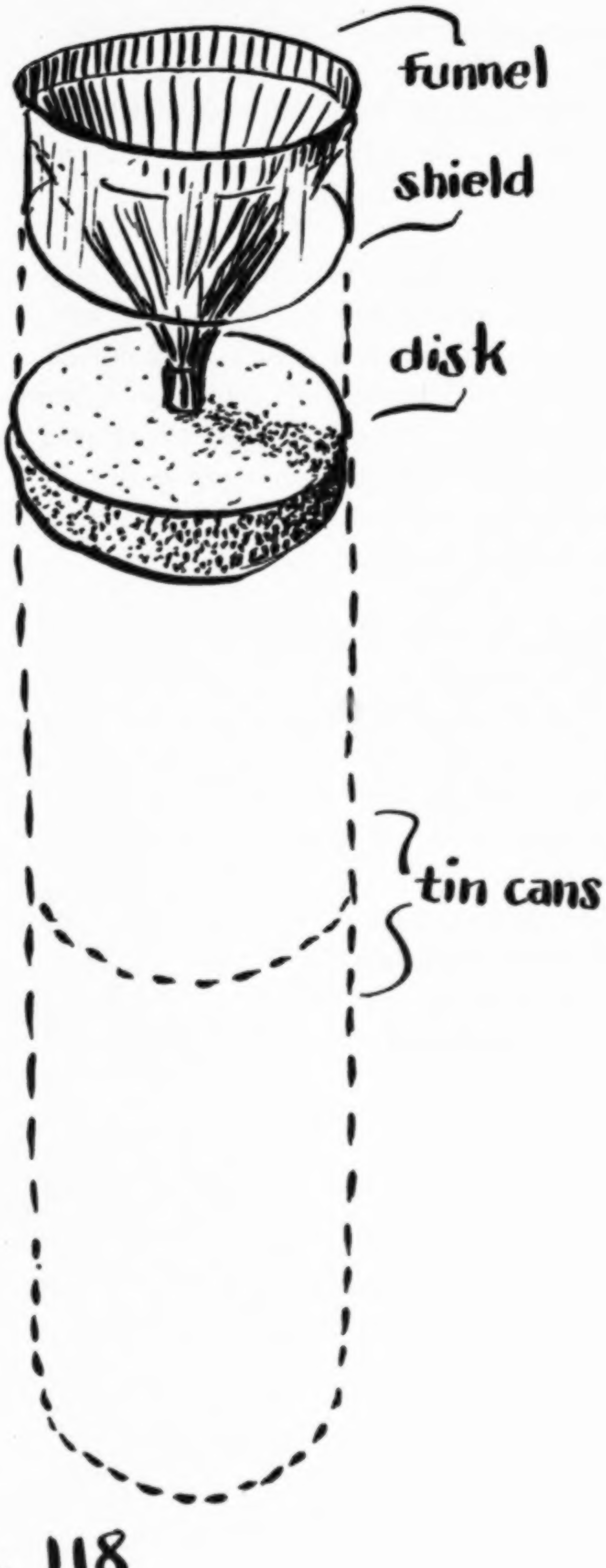

funnel
shield
disk
tin cans

fig. 118

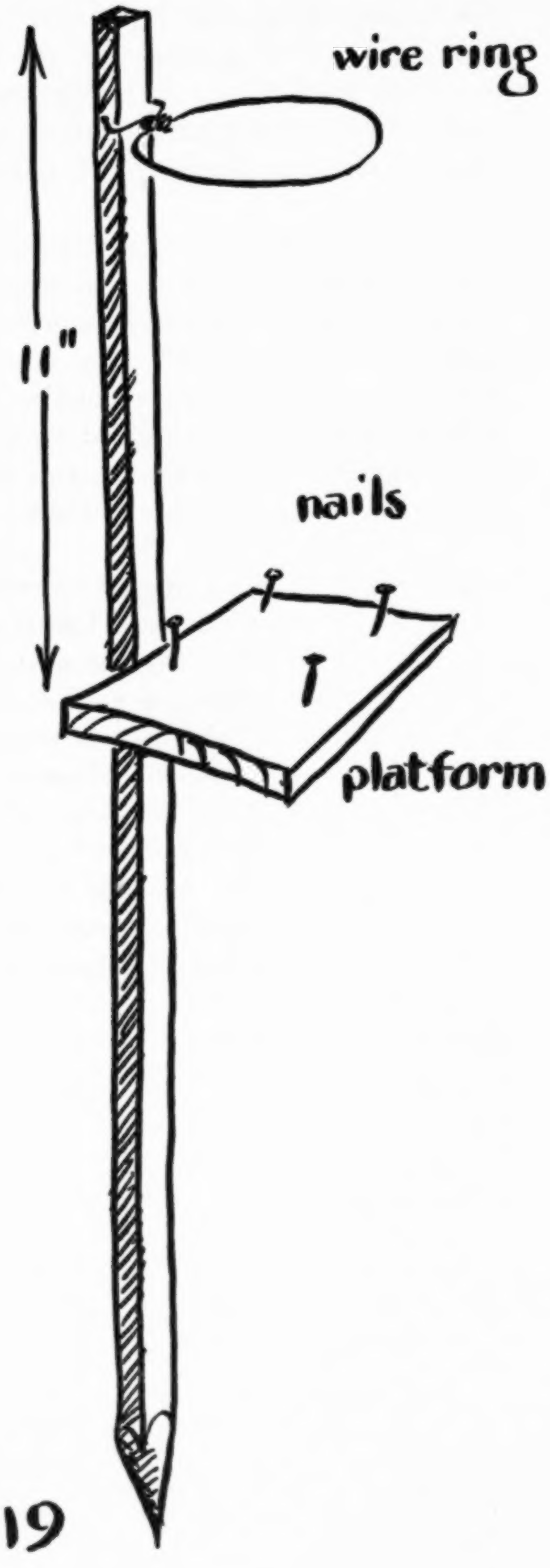

wire ring
11"
nails
platform

fig. 119

45. Snow Measurements.

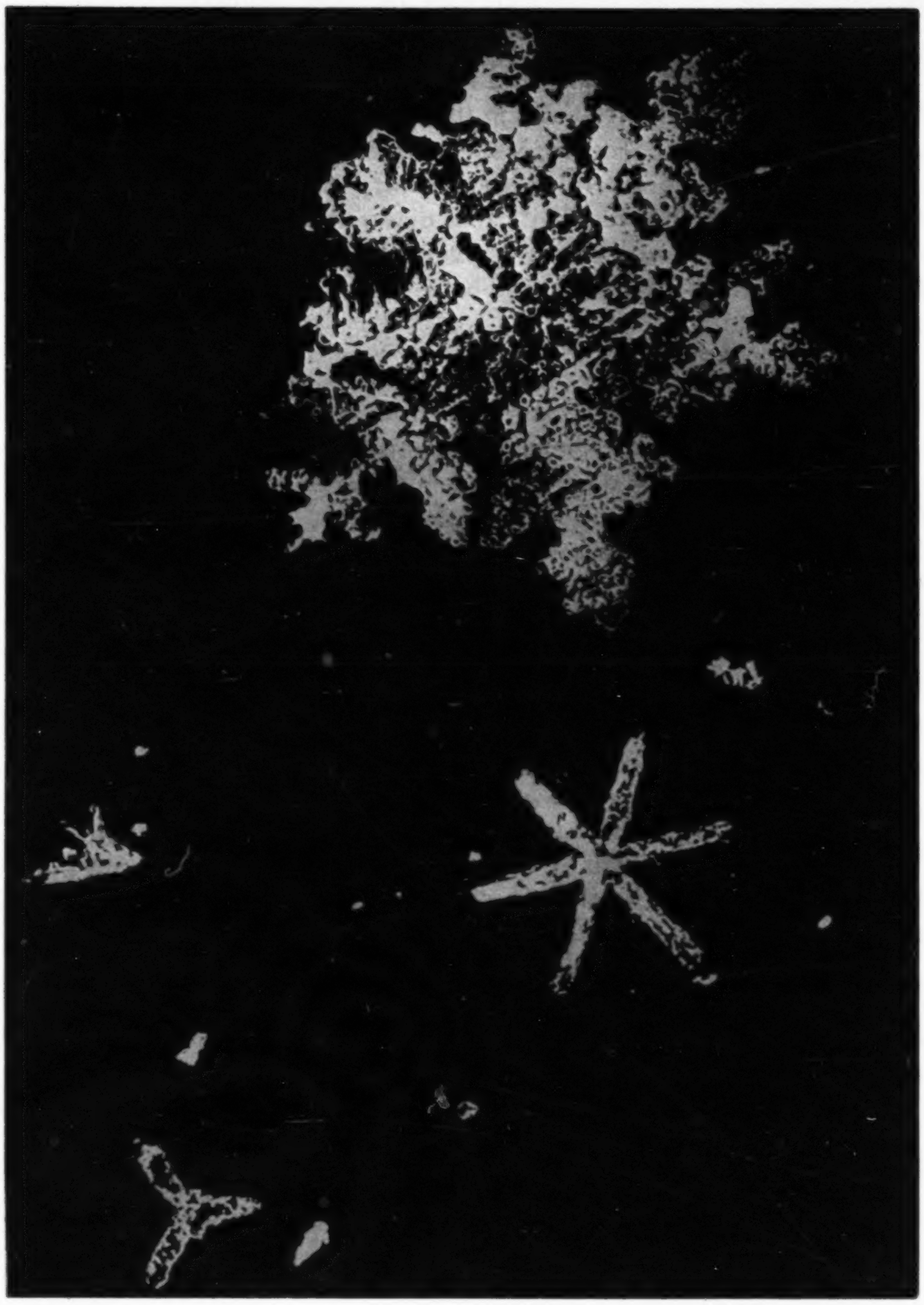


Plate 50. (Magnification 25 times)

In case of snowfall, two measurements are of interest: the depth of the snowcover (preferably separated into the depth of newly fallen snow and total accumulated snow cover) and the water content of the snow; the ratio of the water content to the depth furnishes the snow "density".

The depth of the accumulated snow cover is measured by simply pushing a yardstick vertically through the snow to the ground and reading accurately to 1/10 inch. For this we must select a spot where the snow has not drifted and make several measurements, taking as the final result the average of the various readings. For determining the depth of new snow, we carefully cut with a snow shovel a hole into the snow; the new snow is easily seen on the wall of the hole by its different whiteness and texture.

For measuring the water content of the snow, we use the raingage. Only we remove the funnel, whenever snow is expected instead of rain, because otherwise the snow quickly clogs the funnel and is blown out by the wind or falls off when it piles up on the funnel. At the time of observation we take the can with snow into the room and let the snow melt; to speed up the process, we do not heat the can, but pour a measured amount of hot water (such as a tincan full) into the snow and after melting, pour out the same amount before measuring the snow water in the same manner as we measure rain water. However, we need another conversion chart, because the inner diameter of the can rim is different from that of the funnel rim.

Snow crystal imprints can be obtained by exposing for a short time during a snowfall a small sheet of white cardboard or glass which has been lightly smoked over a candle flame. Care should be taken that the cardboard or glass surface does not become hot during the smoking process, because then the smoke clings to the surface and is not easily disturbed by the snow crystals falling on it. The imprints can be fixed by dipping the sheet into a thin solution of shellac (see Plate 50).

Material:	Raingage construced previously One yardstick One tin can, the top of which has been removed A sheet of white cardboard or glass Shellac, candle
Cost:	35¢

46. Cloud Observations.

Clouds are the result of condensation of invisible water vapor. The various types of clouds and the extent to which they cover the sky depend on the conditions of the atmosphere. For this reason, clouds can give much information on the state of the atmosphere and can furnish clues to impending weather changes.

a. Cloud types: Although no two clouds are ever the same, we can easily distinguish ten different types of clouds according to their general appearances. Since the several types of clouds have been found to occur at different levels above the earth's surface, they have been grouped into four cloud families. The names of the ten cloud types and their abbreviations in ( ) will be given here; for photographs and descriptions of clouds consult elementary texts on meteorology or write to the Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C., for the "Manual of Cloud Forms and Codes for States of the Sky," CIRCULAR, S, U.S. Department of Commerce, Weather Bureau (30¢), or for the U.S. Weather Bureau "Cloud Code Chart" (10¢).

Family A:	HIGH CLOUDS, at heights above 20,000 feet. 1. Cirrus (Ci); 2. Cirrostratus (Cs); 3. Cirrocumulus (Cc).
Family B:	MIDDLE CLOUDS, at heights between 6,500 and 20,000 feet. 4. Altostratus (As); 5. Altocumulus (Ac).
Family C:	LOW CLOUDS, at heights close to the ground up to 6,500 feet. 6. Stratus (St); 7. Stratocumulus (Sc); 8. Nimbostratus (Ns).
Family D:	CLOUDS WITH VERTICAL DEVELOPMENT, ranging from 1,500 feet to level of high clouds. 9. Cumulus (Cu); 10. Cumulonimbus (Cb).

b. Cloudiness: The relative amount of sky covered by clouds, called cloudiness, and the changes in cloudiness are also important for appraising the weather. Cloudiness is expressed in eighths of the visible sky area covered by clouds. This estimation of cloudiness is not as easy to make as it may seem. A simpler method is used for airway weather reports, using five classes of cloudiness:

1. CLEAR, represented by the symbol O; the sky is completely or almost completely free of clouds.
2. SCATTERED, ⦶ ; clouds cover only half of the visible sky area or less.
3. BROKEN, ⦷ ; the cloudy area is larger than the blue sky area, but some blue is still showing.

4. OVERCAST, ⊕ ; there is no, or practically no blue sky visible.

5. OBSCURED, ⊗ ; the sky is not observable because of fog, smoke, haze, etc.

When there are several cloud layers, one can combine the cloudiness symbols with cloud abbreviations to describe the state of the sky in more detail. For example, Cu ⦶, Cs ⊕ would denote "scattered cumulus" with a "cirrostratus overcast" above the cumulus.

c. Cloud Mirror: When the sky is very bright, the glare to the eyes can be avoided by using a black mirror and observing the sky in the mirror. A black mirror can be made of a piece of black, polished glass plate, binding the edges with tape. A less expensive mirror can be made from an ordinary piece of window glass of good quality, by painting the underside black or by fastening a piece of black paper to the underside of the glass plate. The size of the mirror is not critical; the smaller the mirror, the closer it must be held to the eye, in order to see a large portion of the sky. A good size is 8 x 8 " to 12 x 12"; a circular piece of glass makes a nicer mirror. The cloud mirror may be mounted on a post, to the top of which an appropriate piece of wood board has been fastened.

d. Observations: Clouds should be observed and recorded daily at the same time or times, together with other meteorological variables. After a large observational material has been accumulated, one can study the relationship between cloudiness and solar and sky radiation intensity (difference between white- and black-bulb thermometer readings) or other meteorological elements, such as wind direction; or one can investigate whether the cloudiness and cloud types observed in the morning furnish a clue to the weather occurring during the remainder of the day. If morning, noon, and evening observations are available, one can also determine the variation of cloud types and cloudiness during the day.

47. Sky-Blue Observations.

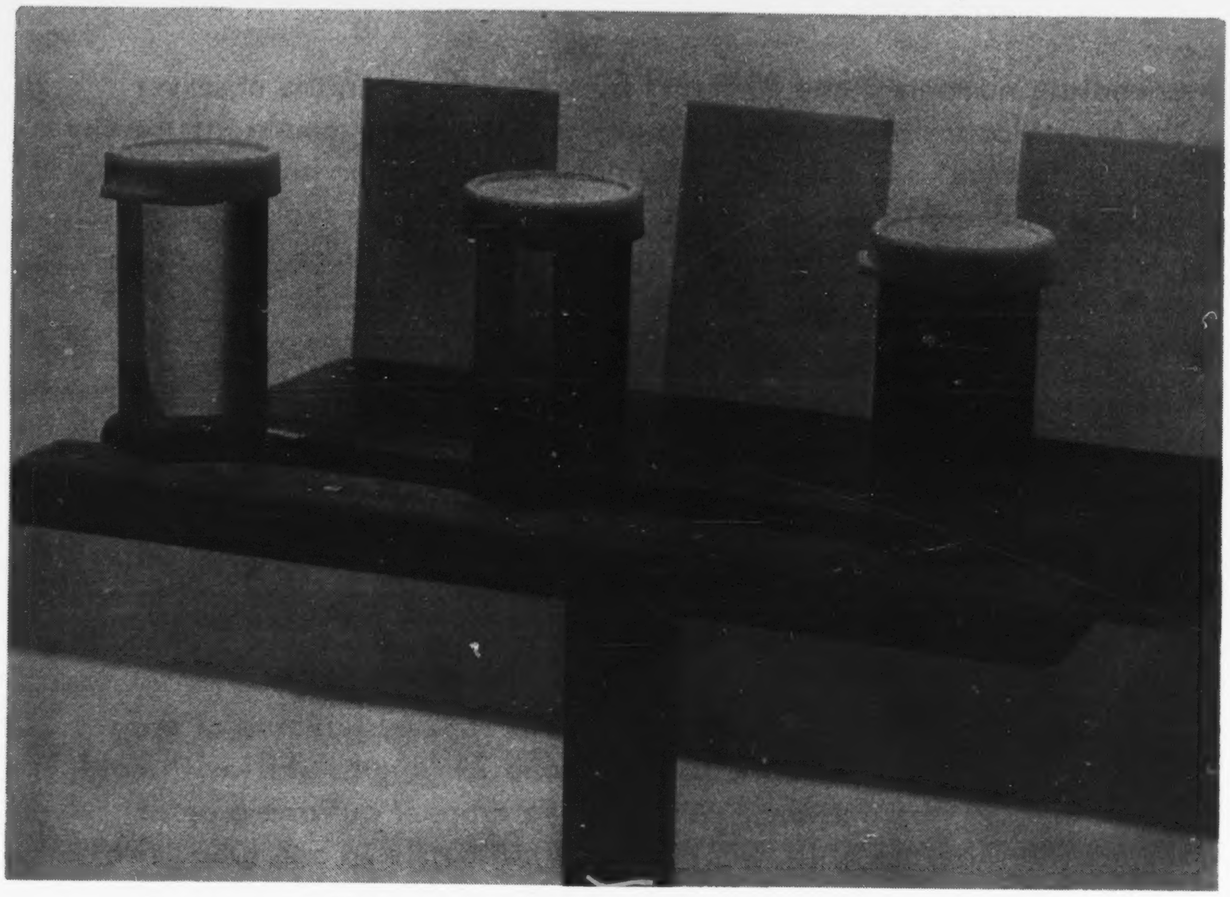


Plate 51.

On a cloudless day, the sky around the zenith (overhead) is deeper blue than near the horizon. This is due to the fact that the dust particles, which make the sky paler blue, are concentrated in the lowest layers of the atmosphere (see Experiment 37). So, when we look upward, our line of sight has a shorter distance through this dusty layer, than when we look toward the horizon (Fig. 120). Observations of the sky-blue are made of the sky area that has the deepest blue color.

Because the blue of the sky has varying admixtures of other colors, depending on the conditions of the atmosphere, the sky color does not only change its saturation between a very deep blue and a very pale blue, but the blueness has also sometimes a greenish tint, sometimes a purplish tint. For this reason it is difficult to devise a scale of different blue saturations with which we could compare the sky-blue. But most people have reliable color memories, so that they can qualitatively judge quite well the saturation of a color.

Let us consider three key (or anchor) points on a qualitative scale of blueness:

No. 1: "Very pale blue" as the sky usually is near the horizon on a clear day;
No. 4: "Medium blue";
No. 7: "Very deep (or dark) blue."

The intermediate numbers 2 and 3, 5 and 6, are used, when the observer judges the sky color to fall between two key points. For example, if the sky is not "very pale blue" (No. 1), but also not quite "medium blue" (No. 4), the observer must decide, whether the sky-blue is nearer to No. 1, in which case he would choose No. 2, or whether the sky-blue is nearer No. 4, in which case he would choose No. 3. Similar choices are made for Nos. 5 and 6.

After a dozen observations of different sky-blue, these estimations become quite easy to make. In the beginning it may help the observer to make himself a blue scale of the three key points, although the different tints of the sky-blue sometimes may make comparison with the scale rather uncertain. The following directions must be followed closely, because the resulting colors are dependent on the quantities prescribed.

Take three 5-dram plastic pill-tubes with caps (obtainable at drug stores); they should have 7/8" inner diameter and 2" length. Fill with cold water to within 1/8" from the top. With an eye dropper put one drop of Carter's Washable Blue Ink (No. 966) from a fresh bottle in one tube, two drops in the second, three drops in the third tube. Put caps on tubes and turn them upside down a few times to mix the ink and water. Empty 2/3 of tube with one drop and fill up with water; this is scale No. 1. Empty 1/3 of the tube with two drops and fill up with water; this is scale No. 4. Empty 1/4 of the tube with 3 drops and fill up with water; this is scale No. 7.

These tubes must be viewed against white paper placed about 5" behind the tubes, with sunlight falling fully on the paper. Use only the middle half of the tube areas seen, as marked in Fig. 121, because the curvature makes the edges of the tubes appear darker. For easier handling of the scale, the tubes can be mounted 2-1/2" apart along one edge of a piece of thin plywood or masonite 5" x 6-1/2". On the opposite edge three pieces of white paper or cardboard 1-1/2" x 2-1/2" are fastened with 1" spaces between them. Through these spaces the sky is viewed and compared with the three shades of the blue scale, as described above (Fig. 122). The instrument shown in Plate 51 is held at arm's length by a handle fastened to the underside of the board.

Estimate the blueness of the sky at the deepest-blue spot, preferably in the forenoon, around noon, and in the afternoon, whenever the state of the sky permits. Keep a record of the estimated scale number, date and time. If possible, other meteorological observations should be made at the same time.

After a sufficiently large observational material has been accumulated, relationships between the sky blue and other meteorological variables, such as wind speed and direction, temperature departures from normal, difference between dry- and wet-bulb temperatures, and solar and sky radiation intensities, and visibility can be studied.

Material: Sheet of thin plywood or masonite 5" x 6-1/2"
Three 5-dram plastic pill-tubes with caps
Three pieces of white paper 1-1/2 x 2-1/2"
Dowel rod 6" long, 3/4" diameter
One small bottle of Carter's Washable Blue Ink No. 966

Cost: 50¢

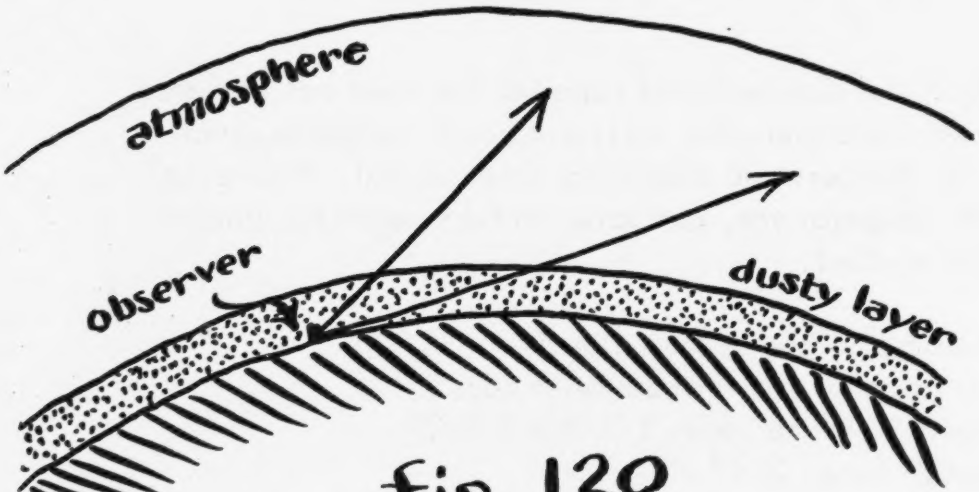

atmosphere
observer
dusty layer

Fig. 120

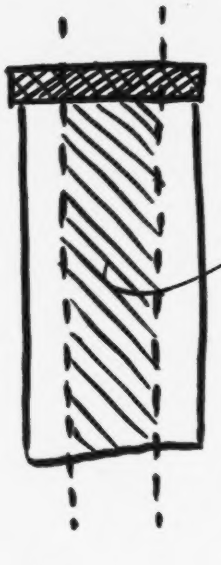

observe through shaded area

Fig. 121

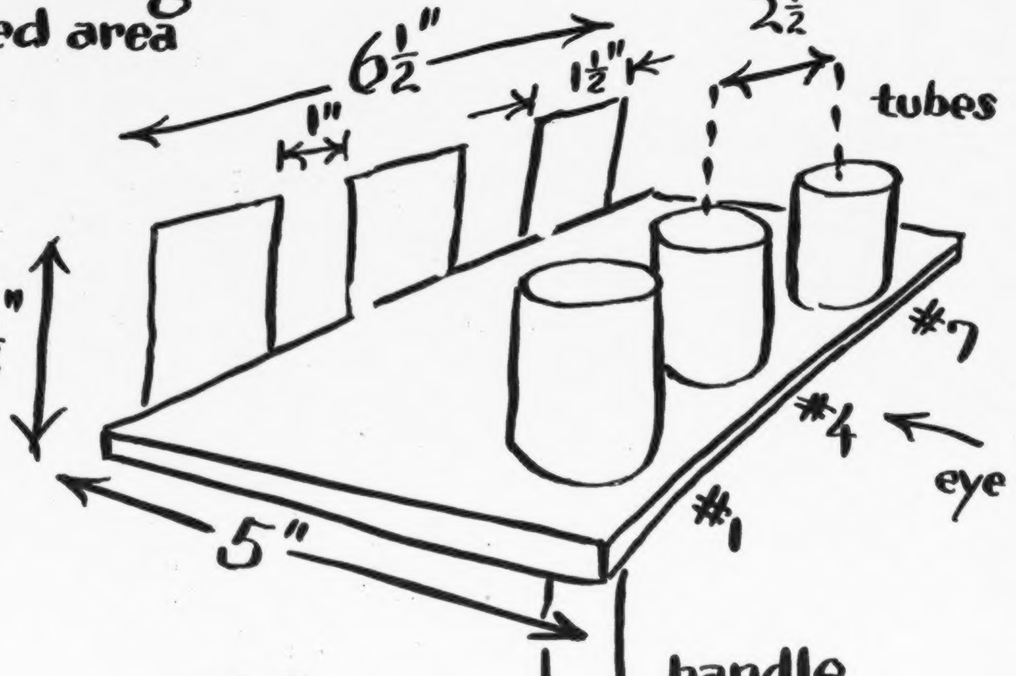

6½"
2½"
1"
1½"
tubes
2½"
#7
#4
eye
#1
5"
handle

Fig. 122

48. Observations of Optical Phenomena.

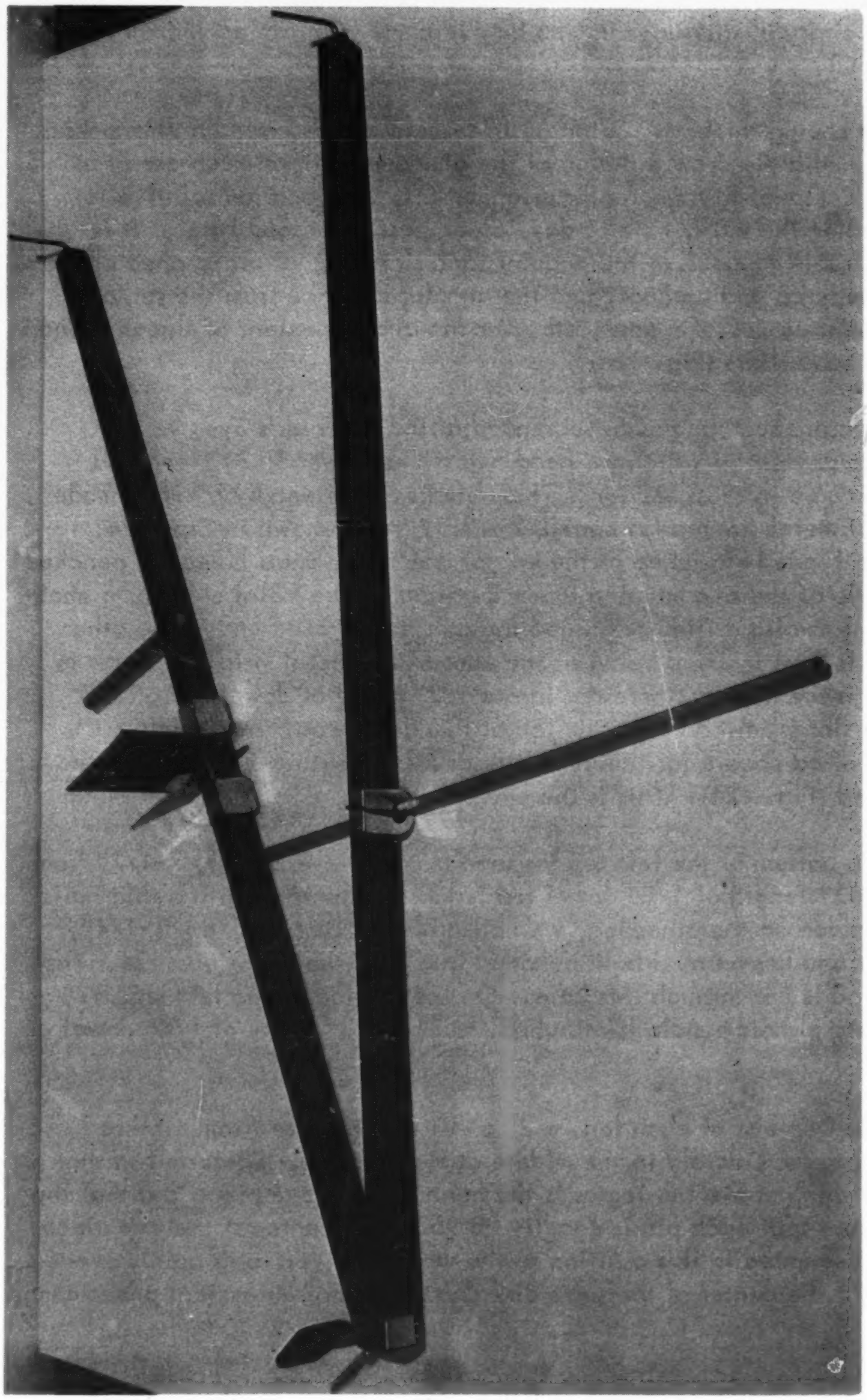


Plate 52.

When we observe the weather regularly and pay more than casual attention to the sky, particularly in the vicinity of the sun, we soon learn that atmospheric optical phenomena are much more frequent than most people realize. Glare is one of the reasons for people avoiding to look toward the vicinity of the sun; this can be overcome with a black mirror (see No. 46,C).

When seeing rainbows, coronas, iridescent clouds, or halo phenomena, we should immediately draw a sketch of the phenomena in as much detail as possible, with respect to form, color arrangement, and location relative to the sun, inluding the date, time of day, cloudiness and cloud types. It is also very desirable to measure the angular radius of ring- or arc-shaped phenomena, such as halos and coronas, and the angular distance from the sun of, e.g., iridescent clouds, sun dogs, etc., or the angular extent of linear phenomena such as sun pillars (Fig. 123).

To measure such angles as subtended at the observer's eye, we can make a simple device for which we need two sticks of wood, 20" long and 3/8 or 1/2" square in cross section. These sticks are joined by a hinge made from a strip of metal (from a tin can) 1/2 x 2-1/2", as shown in Fig. 124. The U-shaped hinge is fastened to the end of one stick; small holes are punched into the middle of the overhanging top and bottom of the metal strip for a small screw. A hole is also drilled or burned through the rounded end of the other stick, which is then inserted between the ends of the metal strip. A screw is pushed through the hole and screwed into a 1/2" piece of dowel rod of 3/8" diameter. A slot is sawed across the top of this dowel rod, into which a 1" square piece of cardboard (or thin masonite or metal) with a 1/4" hole in the center is glued (Fig. 124). This is the eye piece.

At the bottom of the left leg (as seen from the eye piece), 7-1/2" from the pivot, a 12" length of 1/8" dowel rod is loosely fastened with a thin nail. At the same place on the other leg, we nail a piece of metal 5/8 x 1-1/4", which is bent and has an oval hole punched into it as shown in Fig. 124. The 1/8" dowel rod is put through this hole. On the outside of the left leg, 12" from the pivot, a short handle is attached, such as a 3" piece of 1/4" dowel rod (Fig. 125).

At the free end of each leg, a 2" piece of stiff wire (from clothes hanger), bent approximately in the middle at right angles, is inserted so that each pin is as high above the leg as is the center of the eye piece and that the distance of the tip of each pin is exactly 20" from the center of the eye piece. The pins are cemented in this position to the wood; they serve as points over which we sight the center of the sun's disk and a point of an optical phenomenon (Fig. 125).

To be able to look at the sun, we take a 2 x 2" piece of overexposed photographic film, or welding glass, or ordinary glass smoked over a candle flame. This sunshade is cemented to a piece of wood 1/2 x 1/2 x 2", and a nail put through the middle of the wood (Fig. 126); a corresponding hole in the middle of each leg enables us to place the shade on either side.

For observing, we hold the instrument by the handle with the left hand, the thin dowel with the right hand, and put our eye close to the eye piece. We sight the sun's center over one pin, the optical phenomenon over the other pin. When both are lined up properly (Fig. 127), we hold the thin dowel tight against the right leg and measure with a yard stick or inch scale the distance between the pins in inches and fractions of an inch, converting the fractions to decimals. The angle A is found by sin(A/2) = D/40, where D is the distance between the pins in inches. (Fig. 128).

The radius of rainbows can be found by measuring the angular distance between the center of the shadow of one's head and a point on the rainbow.

Material:
Two sticks of wood, 1/2 x 1/2 x 20"
One piece of wood 1/2 x 1/2 x 2"
One 12" length of 1/8" dowel rod
One 3" piece of 1/4" dowel rod
One 1/2" piece of 3/8" dowel rod
One piece of tin-can metal 1/2 x 2-1/2"
One piece of tin-can metal 5/8 x 1-1/4"
One piece of cardboard 1" square
One overexposed film of glass, 2" square
Two 2" pieces of stiff wire
Glue, nails, one screw, yardstick

Cost: 25¢

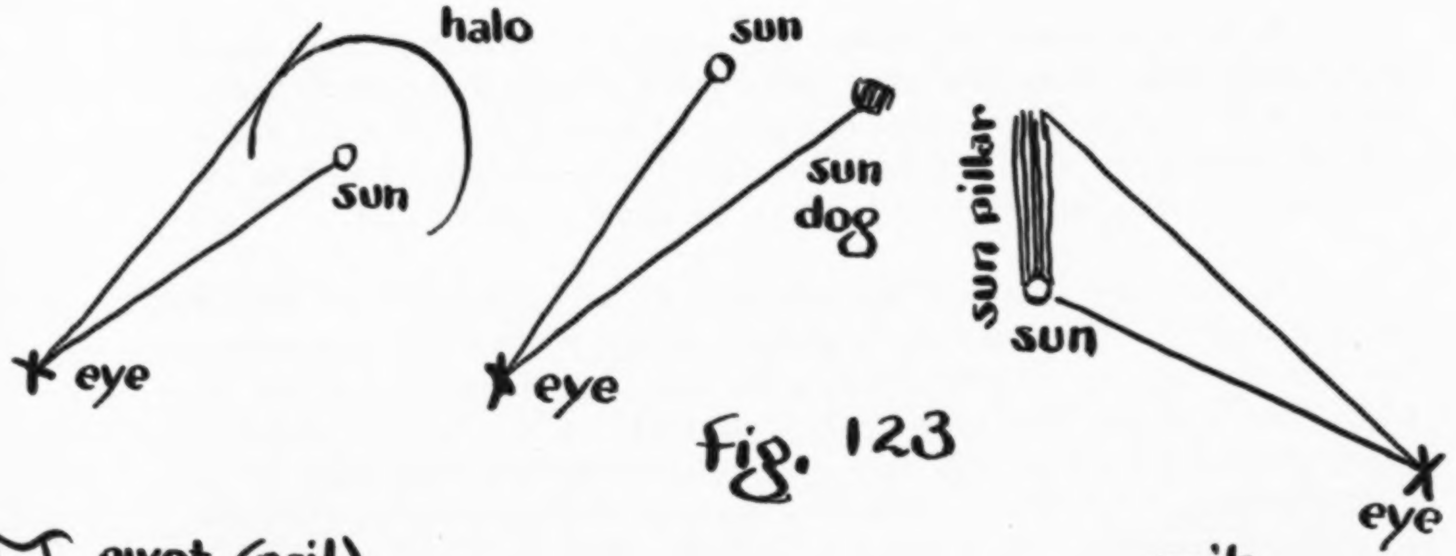

halo
sun
eye
sun
sun dog
eye
sun pillar
sun
eye

fig. 123

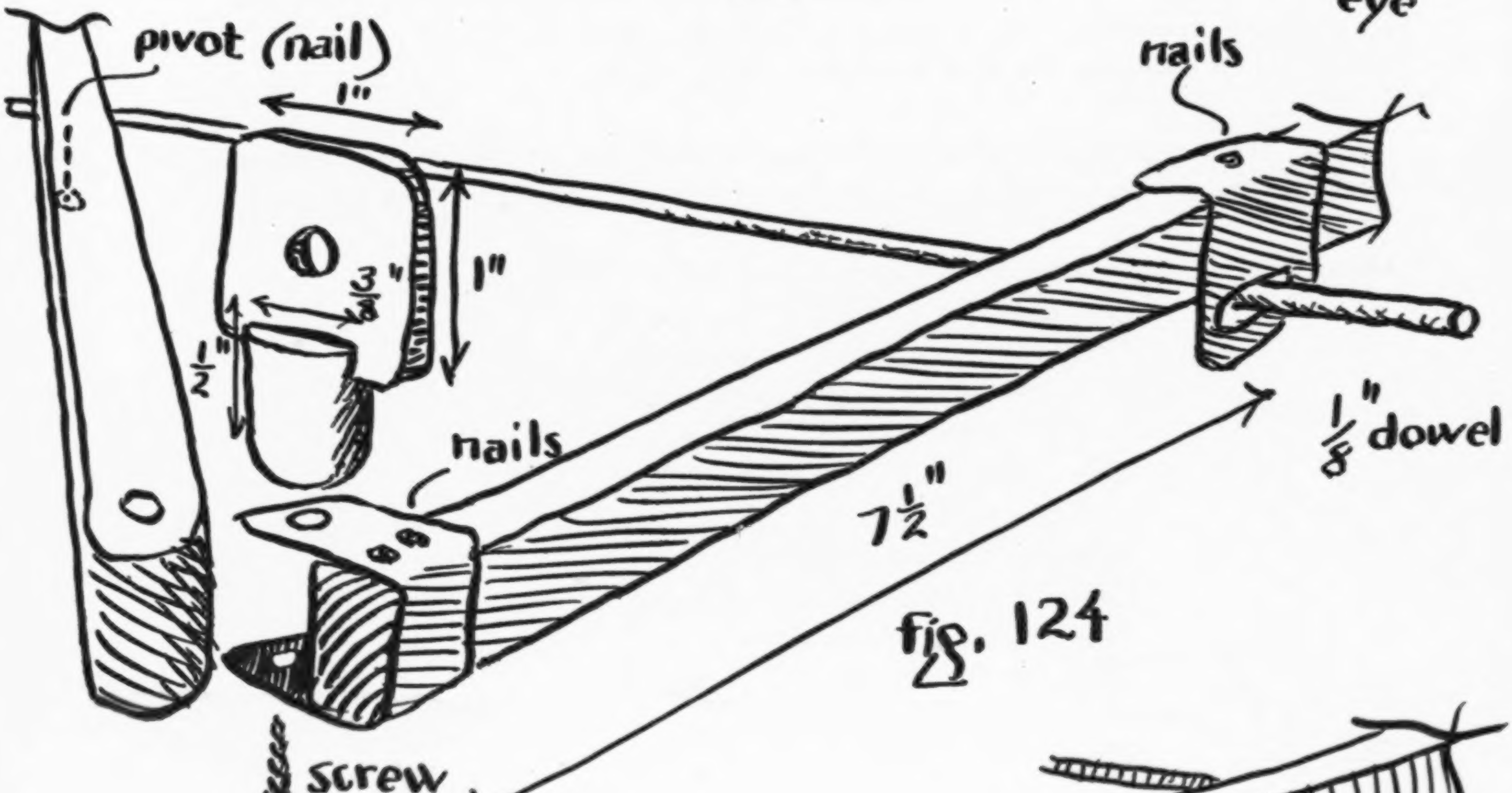

pivot (nail)
1"
1"
3/8"
1/2"
nails
nails
1/8" dowel
7 1/2"
screw

fig. 124

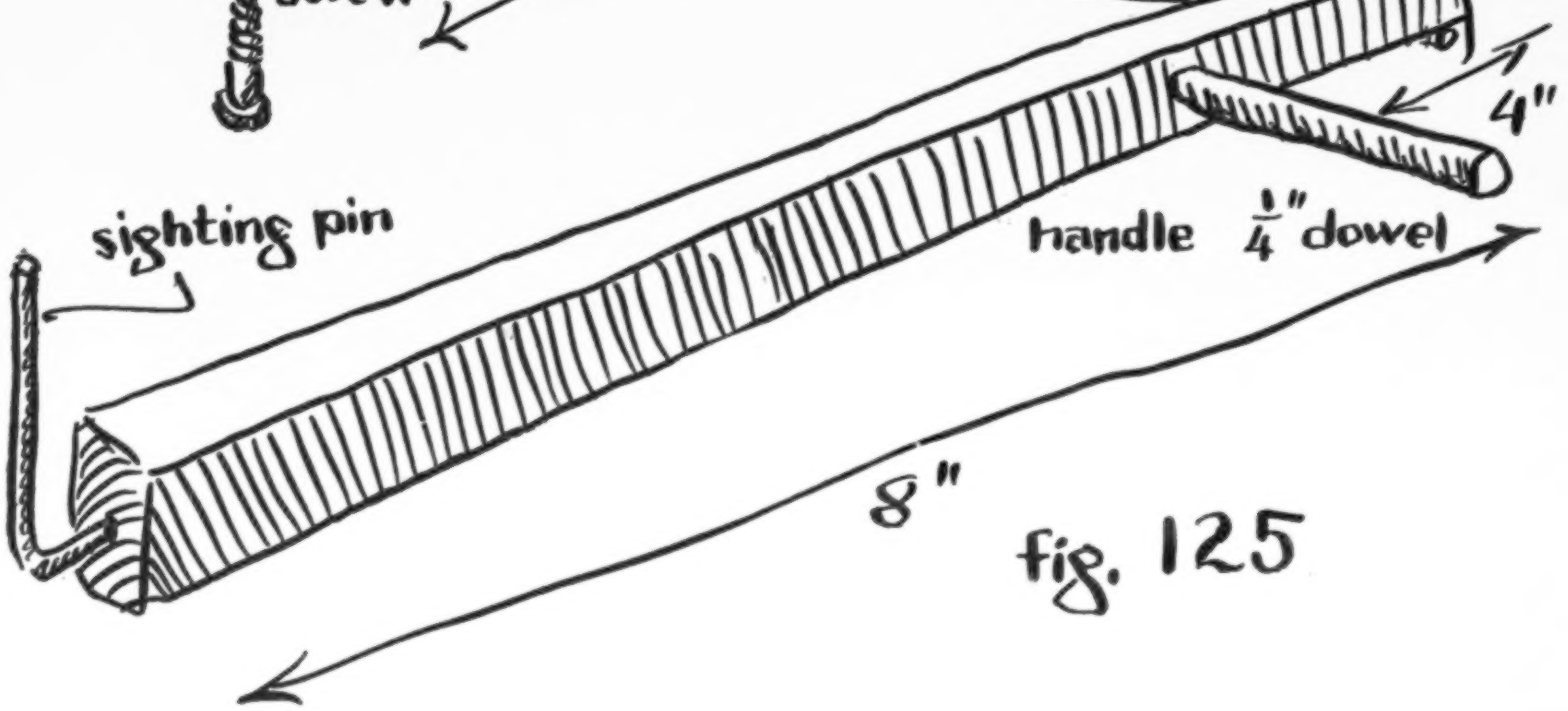

sighting pin
handle 1/4" dowel
4"
8"

fig. 125

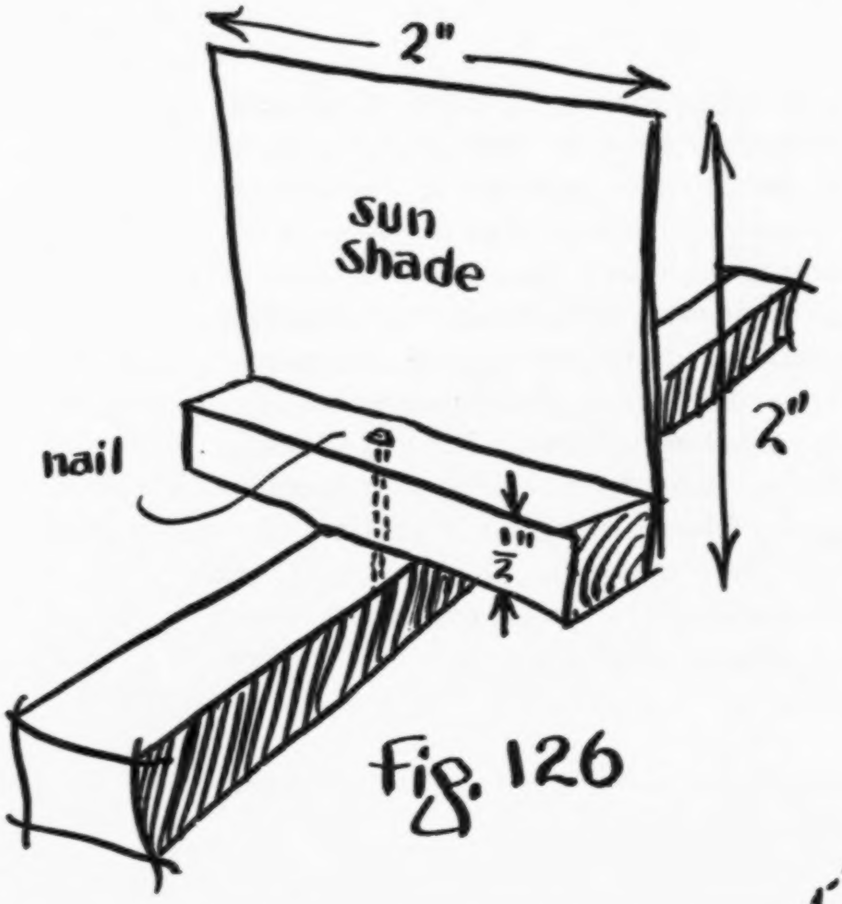

2"
sun Shade
2"
nail
1/2"

fig. 126

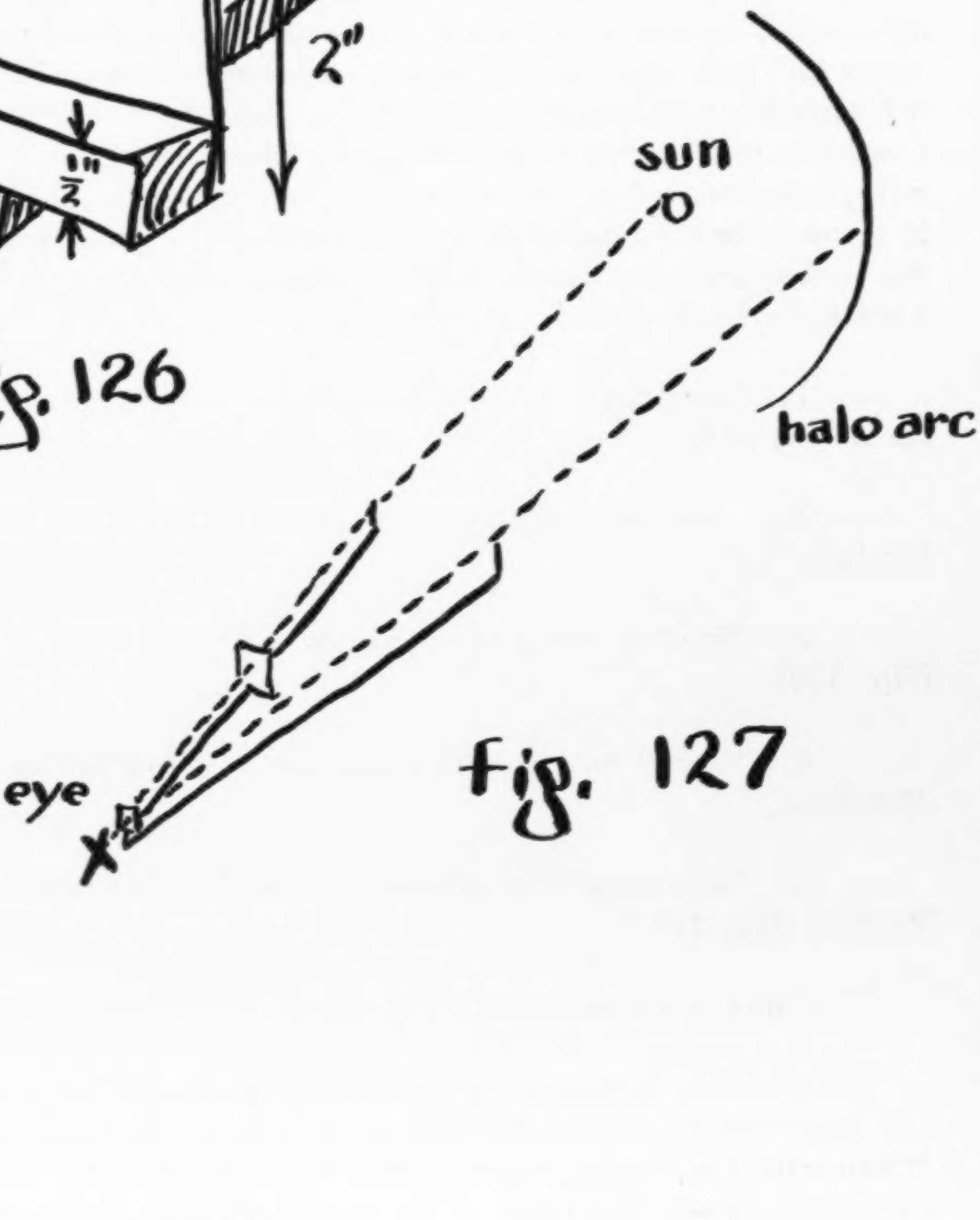

sun
halo arc
eye

fig. 127

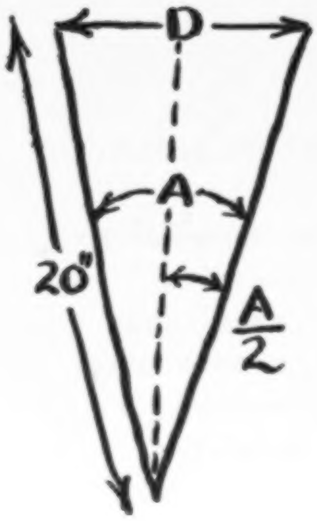


fig. 128

49. Visibility Observations.

The transparency of the air, as judged by the visibility of objects through it reveals much about the character of the air mass present, particularly the stability or instability of the air layer adjacent to the surface. Visibility is the farthest horizontal distance, in miles and/or fractions of miles, at which prominent dark objects can be seen against the horizon sky. For estimating visibility the observer must have in his environment a number of suitable objects, such as dark buildings, tree groups, forested hills, etc., located at different, known distances. This requirement is rarely fulfilled, especially at amateur weather stations. For this reason, it is probably more adequate to estimate visibility according to a qualitative scale, such as was suggested for sky-blue estimations in section 47. Here, however, a five-step scale with three anchor point (Nos. 1, 3, and 5) seems to be more appropriate than a seven-step scale, especially where the number and distances of visibility targets is severely restricted. Such a scale can be described as follows:

1. "Very poor" for conditions of dense haze or fog, etc., corresponding to visibilities of less than 1/2 mile (Fig. 129).

2. "Poor" for foggy or hazy conditions with visibilities of 1/2 to 2 miles.

3. "Fair" for average conditions with visibilities of 2 to 10 miles (Fig. 130).

4. "Good" for clear-air conditions with visibilities between 10 and 30 miles.

5. "Very good" for extremely clear air with visibilities of more than 30 miles (Fig. 131).

Other, more detailed scales can be used where local conditions permit.

Visibility estimates are made at the same time daily as other meteorological observations. When visibility is "very poor" or "poor" due to socalled "Obstructions to Vision," such as fog, haze smoke, dust, or drifting snow (but not precipitation), the cause of the restricted visibility is entered in the weather log under a separate heading: "Remarks." After a considerable amount of observational material has been collected, relationships between visibility and other meteorological variables can be studied.

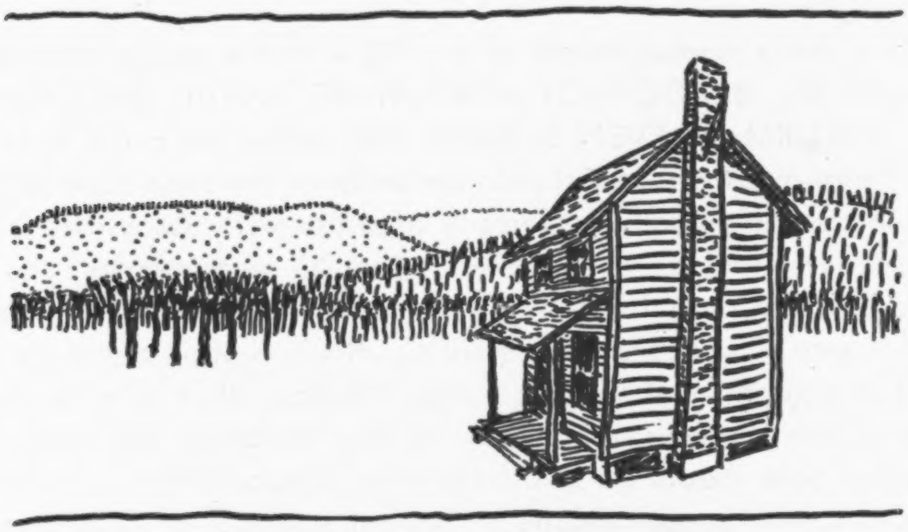


fig. 131

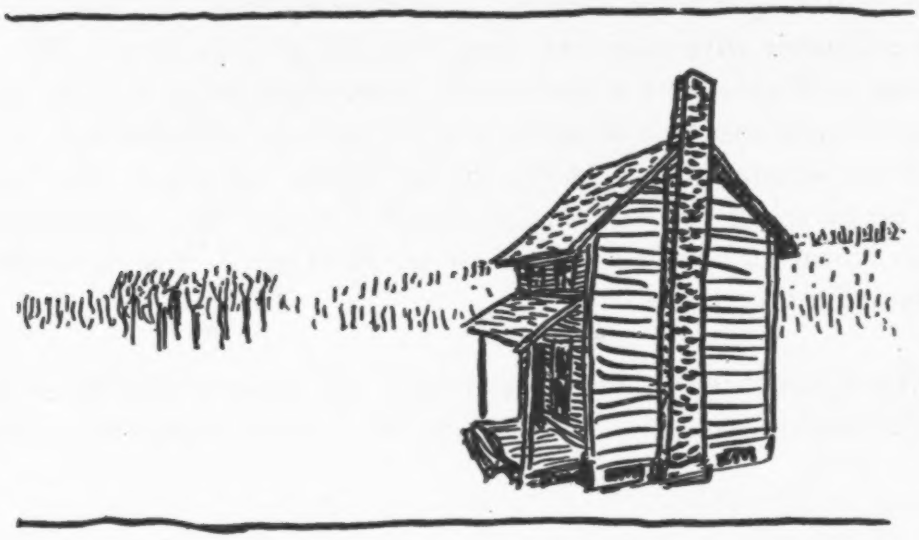


fig. 130

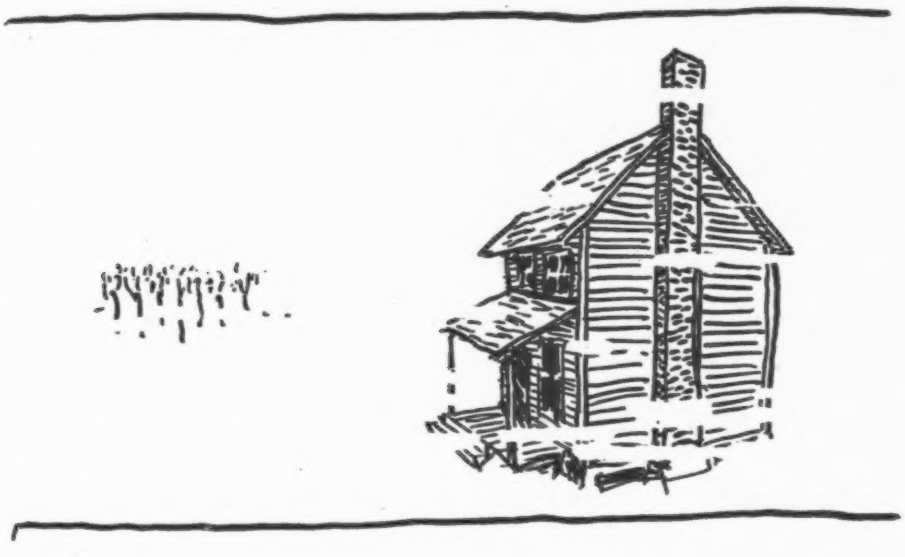


fig. 129

50. Potential Gradient Observations.

Make daily measurements of the PG with the equipment described in Experiment 38. But DO NOT MEASURE POTENTIAL GRADIENT DURING A THUNDERSTORM OR EVEN DURING THE APPROACH OF A THUNDERSTORM. These measurements should be made at the same time or times every day for an extended period, preferably together with observations of other meteorological variables. The place for the PG measurements should be selected so that the conditions of the surroundings remain fairly constant. If a flat roof is easily and safely accessible, this is a good place for observing the PG. The equipment should be stored indoors. If it rains or snows during observations, the electrometer as well as the insulation and collector on top of the wooden pole should be protected from precipitation. In case of the fuse collectors, this is easily done by fastening a roof of aluminum foil to the top of the insulating candle with pins, so that neither the roof nor the pins touch the collector wire and fuse (see Plate 42 of Experiment 38). In case of the flame collector, the aluminum-foil wind shielding can be covered with an additional sheet of aluminum foil that extends over the cylinder and the supporting wooden pole. A few holes for the escape of the flame gases must then be punched around the top rim of the cylinder. In case of the water-drop collector, only the insulation, from which the can with water is hung, must be protected.

After a sufficiently large observational material has been collected, various relationships to other meteorological variables can be studied.

IV. INEXPENSIVE READING MATERIAL

Books:

Battan, Louis J.: The Nature of Violent Storms. Anchor Books, Doubleday and Company, Inc., Garden City, New York, 1961 ($. 95)

Battan, Louis J.: Radar Observes the Weather. Anchor Books, Doubleday and Company, Inc., Garden City, New York, 1962 ($ .95)

Clausse, Roger, and Facy, Leopold,: The Clouds. (Evergreen Profile Book 30), Grove Press, Inc., New York, 1961 ($1.35)

Lehr, P. E., Burnett, R. Will, and Zim, Herbert S.: Weather. A Golden Nature Guide, Golden Press, New York, 1961 ($1.00)

Loebsack, Theo: Our Atmosphere. Mentor Bood (MD309), the New American Library, New York, 1961 ($ .50)

Minnaert, M.: The Nature of Light and Colour in the Open Air. Dover Publications, Inc., New York, 1954 ($1.95)

Orr, Clyde Jr.: Between Earth and Space. Collier Books, New York, 1961 ($ .95)

Scorer, R. S.: Weather. Progress of Science Series, Phoenix House, London, Roy Publishers, New York, 1959 ($1.50)

Smith, L. P.: Weathercraft. Blandford Press, London, 1960 ($1.50)

Spilhaus, A. F.: Weathercraft. The Viking Press, New York, 1951 ($2.00)

Sutton, O. G.: Understanding Weather. Penguin Books, Baltimore, Md., 1960 ($ .95)

Periodicals:

Weather. Published by the Royal Meteorological Society, 49 Cromwell Road, London S.W. 7, England. ($3.90 per year)

Weatherwise. Published by the American Meteorological Society, 45 Beacon Street, Boston 8, Mass. ($4.00 per year)

For additional reference reading write for An Annotated Meteorological Bibliography for Secondary Schools, U.S. Department of Commerce, Weather Bureau, Washington, D.C. October 1960, to the Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C. ($ .10)